Total Maximum Daily Load
Cooper River, Wando River, Charleston Harbor System
South Carolina

Watershed Number	Waterbody
03050201-010	Tail Race Canal
03050201-030	West Br. Cooper River
03050201-040	East Br. Cooper River
03050201-050	Cooper River
	Shipyard Creek
	Town Creek
03050201-060	Back River/Cooper River
03050201-070	Goose Creek
03010201-080	Wando River
03010202-070	Charleston Harbor

Parameter of Concern: Dissolved Oxygen

South Carolina Department of
Health and Environmental Control
Bureau of Water

December 16, 2002

Wade M. Cantrell
Larry E. Turner

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South Carolina Department of Health
and Environmental Control

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EXECUTIVE SUMMARY

The Charleston Harbor Estuary is located centrally on the South Carolina coast. It is composed of Charleston Harbor and its tributaries: the Ashley River, the Cooper River and the Wando River. The system is tidally influenced throughout. Separate total maximum daily loads (TMDLs) for oxygen demanding substances are developed for the Ashley River portion of the system and for the Harbor, Cooper River and Wando River portion of the system. This report documents TMDL development for the Harbor/Cooper/Wando portion of the system.

Section 303(d) of the Clean Water Act and the Environmental Protection Agency=s (EPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require the states to establish TMDLs for all waterbodies. Priority is given to development of TMDLs for waterbodies identified under Section 303(d)(1)(A) and (B) as not meeting applicable water quality standards. For the purpose of information, TMDLs are to be established for those waterbodies not identified as impaired. With the exception of two stations on the Ashley River (CSTL-102, Ashley River @ SC 165 and MD-049, Ashley River @ Magnolia Gardens) and one station on the Wando River (MD-115, Wando River @ SC 41), South Carolina Department of Health and Environmental Control (DHEC or the Department) ambient monitoring stations in the Charleston Harbor system are not considered to be impaired under criteria of Section 303(d) of the Clean Water Act. However, available information indicates much of the system does not meet the applicable water quality standard for dissolved oxygen for significant periods of time and, therefore, is considered water quality limited for the purposes of wasteload allocation (WLA) development. WLAs are an integral part of a TMDL. While all WLAs for water quality limited segments are not developed through the TMDL process, the Department, with EPA=s concurrence, has chosen to use the TMDL process to develop wasteload allocations for dischargers to the Charleston Harbor system. This allows for a more coordinated WLA process in this multi-discharge system, greater public review and comment, and more formal review and input by EPA Region 4.

Previous modeling work, available instream water quality data for the Charleston Harbor system, and information available on tidal estuaries un-impacted by point source discharges of pollution indicate that, during the critical periods for which wasteload allocations are set, dissolved oxygen (DO) concentrations in much of the Charleston Harbor system are low and would not meet applicable standards even without discharger input of oxygen demanding substances. Under such circumstances where DO concentrations are naturally low, State water quality standards (R.61-68.D.4.a.) allow a lowering of DO of no more than 0.1 mg/l.

A water quality model was developed to predict the impact of point source discharges on DO concentrations in the system. The model incorporated appropriate critical conditions, instream processes, and decay rates. Results indicate the need for an overall reduction in discharge of oxygen demanding substances to the system of approximately 70%. A phased approach to achieving these reductions is proposed with an initial Phase 1 reduction of approximately 60%. The TMDL allows for additional study and modeling during Phase 1 to further refine the allowable load to the system prior to implementation of final limits.

PROJECT SETTING

Charleston Harbor is centrally located on the South Carolina coast and encompasses an area of 65 sq. miles, 40 sq. miles of which are marsh and lowlands. It is formed at the confluence of the Ashley, Cooper, and Wando Rivers, which drain an approximately 1,200 square mile region, and exchanges directly with the Atlantic Ocean (See Figure 1). Historically, the Ashley, Wando, and Cooper Rivers were all tidal sloughs with limited freshwater inflow and extensive tidal marshes. The Ashley River (approximately 30 miles in length) and the Wando River (approximately 20 miles in length) remain tidal sloughs with varying levels of urban development along their reaches. Via diversion of water from the Santee River basin, the Cooper River now carries significant freshwater and flows 48 miles from the tailrace of Pinopolis Dam to the Customs House Wharf. The Harbor/Cooper/Wando system will be covered by one TMDL. The Ashley River, which under low flow conditions contributes little to no freshwater input to the system, will be covered by a separate TMDL.

Over its history, Charleston Harbor and its tributaries have undergone extensive anthropogenic changes. In the 17th and 18th centuries, rice plantations were created in the upper Cooper and Ashley Rivers by extensive diking of intertidal wetlands. Remnants of these fields can be seen above the ATee@ where the Cooper River splits into the East and West Branches and along the upper Ashley River. Prior to 1941, the Cooper River was a tidally-dominated stream, entirely confined to the coastal plain, with a net seaward discharge of approximately 70 ft^3/s. In 1941, the Santee-Cooper Project was completed by the South Carolina Public Service Authority (SCPSA) in response to increased demands for hydroelectric power. Dams were built on the Santee and Cooper Rivers forming Lakes Marion and Moultrie, respectively. The elevation difference between Lake Moultrie and the Cooper River is approximately 55 ft greater than the difference between Lake Marion and the Santee River. To take advantage of this greater elevation difference, a diversion canal was constructed between Lake Marion and Lake Moultrie, diverting flow from the Santee River basin to the Cooper River. With diversion, the Cooper River annual mean discharge increased to approximately 15,000 ft^3/s. Due to severe shoaling in the harbor, the Army Corps of Engineers developed and executed plans to re-divert a portion of the Cooper River flow back to the Santee River. Since rediversion, which was fully implemented by August 1985, a flow agreement between the Corps of Engineers and SCPSA has established a goal of a weekly average discharge from Lake Moultrie to the Cooper River of 4,500 ft^3/s with an allowance for lower flows. Other changes to the system include significant port development with associated navigation channel dredging and the creation of a freshwater reservoir by diking the mouth of a tidal slough (Back River) and connecting the upper portion of the slough to the freshwater portion of the West Branch of the Cooper River by construction of Durham Canal. Additional information on the system is included in EPA=s ACharleston Harbor TMDL Model Review,@ attached as Appendix A.

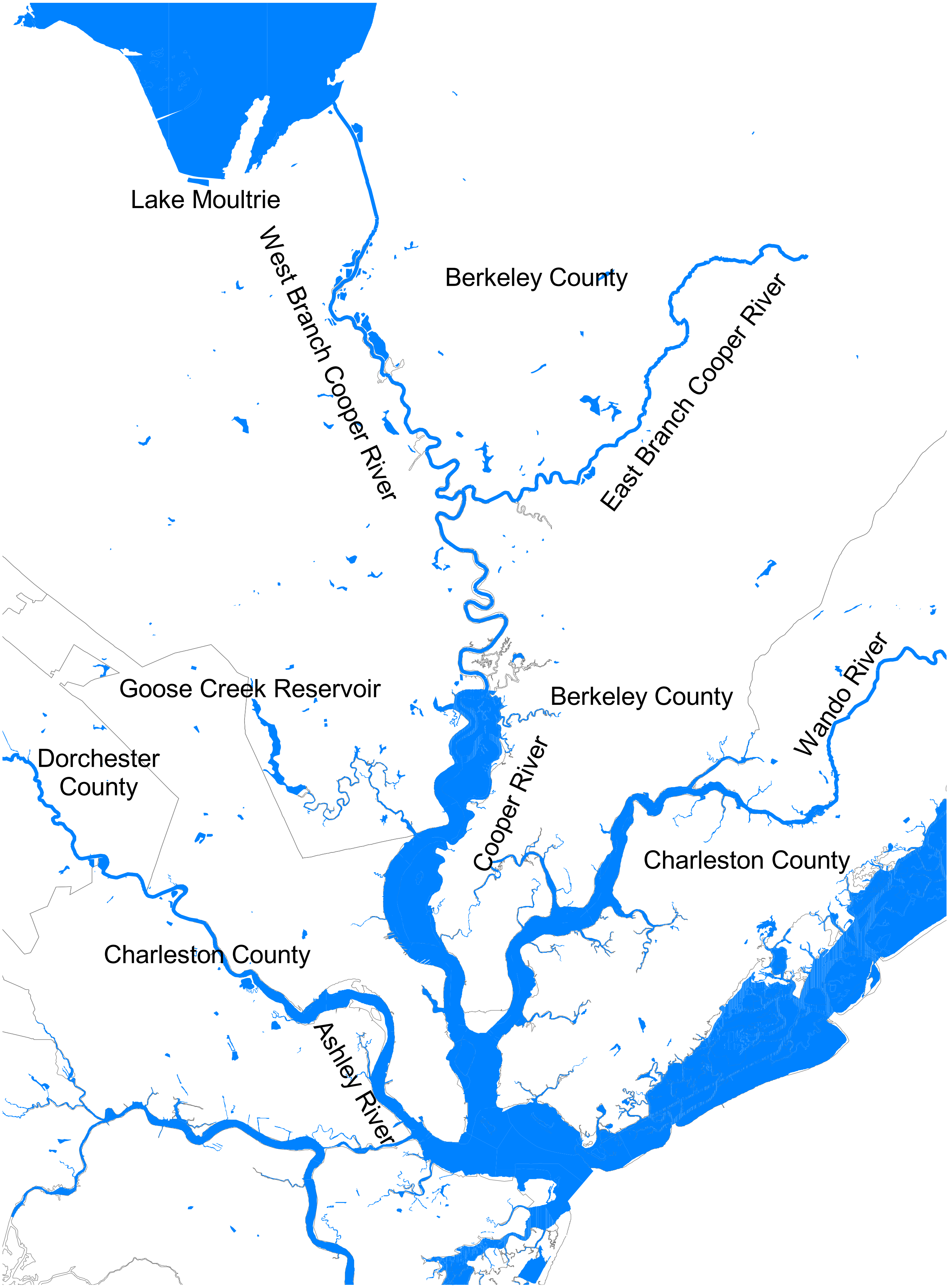

Figure 1. Site Location Map

BASIS FOR ESTABLISHING TMDL

Introduction

Section 303(d) of the Clean Water Act and EPA=s Water Quality Planning and Management Regulations (40CFR Part 130) require states to develop TMDLs to protect state waters. TMDLs are required for all waters; however, priority is given to those waters identified under section 303(d)(1)(A) as not meeting applicable water quality standards. For those waters not identified as impaired, TMDLs for the specific purpose of developing information are required but only as State resources allow (40 CFR 130.7(e)). The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and instream water quality conditions, so that the states can establish water quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991). With the exception of 2 stations in the Ashley River (CSTL-102, Ashley River @ SC 165 and MD-049, Ashley River @ Magnolia Gardens) and one station on the Wando River (MD-115, Wando River @ SC 41), DHEC ambient water quality stations in the Charleston Harbor System, which are sampled once a month, are not considered impaired for dissolved oxygen under the criteria of Sections 303(d) and 305(b) of the Clean Water Act. However, continuous ambient water quality data collected by the U. S. Geologic Survey (USGS) as part of the Charleston Harbor Project and initial water quality modeling results by USGS indicate that much of the system will not meet the standard under the critical conditions deemed appropriate for determining wasteload allocations to be included in NPDES permits for dischargers to the system. For this reason, the waterbody is considered water quality limited. While wasteload allocations for water quality limited streams can be developed without utilizing the TMDL process, DHEC, with EPA=s concurrence, has chosen to use the TMDL process to develop wasteload allocations for the Charleston Harbor system. This allows a more coordinated process for determining allowable loading of oxygen demanding substances from the multiple discharges to the system. It also allows for greater public participation in the process, from both the general and regulated public, and for more formal review and input by EPA Region 4.

Due to the complexity of the situation, the number of discharges involved, the conservative nature of the current 2 dimensional (2-D) model, recent advancements in model and computing abilities, and the impacts associated with implementation of the TMDL, DHEC has determined it appropriate to implement required reductions in two phases. Phase 1 would require a reduction from current permitted loadings of approximately 60%. Final loadings, which would require an approximate 70% reduction from current permitted loadings, would be implemented in Phase 2. A specified time frame will be allotted in Phase 1 to allow the local Council of Governments, in coordination with the affected discharges, to conduct additional studies and modeling to potentially refine the final TMDL loadings.

Problem Definition

Charleston Harbor and its tributaries are a complex estuarine system encompassing ecosystems ranging from salt to fresh open water habitats to intertidal saltwater and freshwater marshes. The Cooper River is the only tributary to the harbor that carries significant freshwater, this coming from the diversion of water from the Santee River basin to the Cooper River via the diversion canal between Lakes Marion and Moultrie and the tailrace canal which connects Lake Moultrie to the West Branch of the Cooper River. The Ashley and Wando Rivers are essentially tidal sloughs that carry limited fresh water from their relatively small drainage basins.

Intertidal estuarine systems are characterized by highly variable salinity and dissolved oxygen concentrations. Available information on these systems shows that dissolved oxygen concentrations frequently fall below the criteria established for such waters which are usually either Aa daily average of 5.0 mg/l with a low of 4.0 mg/l@ (class Freshwater) or Anot less than 4.0 mg/l@ (class SB waters). These excursions are found during high temperature periods whether or not there are anthropogenic sources of oxygen demand to the system. The Antidegradation Rules of South Carolina=s water quality standards (R.61-68.D.4) recognize that natural conditions may cause a depression of dissolved oxygen in surface waters below the numeric standard while existing and classified uses are still maintained. This section states:

> 4. Certain natural conditions may cause a depression of dissolved oxygen in surface waters while existing and classified uses are still maintained. The Department shall allow a dissolved oxygen depression in these naturally low dissolved oxygen waterbodies as prescribed below pursuant to the Act, Section 48-1-83, <u>et seq</u>., 1976 Code of Laws:
>
> > a. Under these conditions the quality of the surface waters shall not be cumulatively lowered more than 0.1 mg/l for dissolved oxygen from point sources and other activities, or
> >
> > b. Where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable water quality standard established for that waterbody, the minimum acceptable concentration is 90 percent of the natural condition. Under these circumstances, an anthropogenic dissolved oxygen depression greater than 0.1 mg/l shall not be allowed unless it is demonstrated that resident aquatic species shall not be adversely affected. The Department may modify permit conditions to require appropriate instream biological monitoring.

Section 4(a) is referred to as the 0.1 Rule while section 4(b) is referred to as the 10% Rule.

During the early stages of the Charleston Harbor modeling project, the Department observed, based on continuous monitoring conducted by the USGS, that much of the Charleston Harbor system did not meet applicable water quality standards for dissolved oxygen during critical, high temperature conditions. The analysis described in Appendix B, AApplication of the 0.1 Rule to the Charleston Harbor System,@ concluded that the low dissolved oxygen concentrations were a natural phenomenon that was further impacted by point source discharges. Appendix B also includes a table showing the range of DO concentrations found during the months June through October at the 15 stations in the system where USGS collected continuous DO monitoring. The

Department, with concurrence from a modeling workgroup composed of representatives of EPA, USGS, the University of South Carolina (USC), the S.C. Coastal Conservative League, and Applied Technology and Management (ATM, consultants for the Cooper River Water Users Association), determined that the 0.1 Rule should apply to the Charleston Harbor system.

Waterbodies Impacted

Watershed Number	Waterbody	County
03050201-010	Tail Race Canal	Berkeley
03050201-030	West Br. Cooper River	Berkeley
03050201-040	East Br. Cooper River	Berkeley
03050201-050	Cooper River	Berkeley
	Cooper River	Charleston
	Shipyard Creek	Charleston
	Town Creek	Charleston
03050201-060	Back River/Cooper River	Berkeley
03050201-070	Goose Creek	Berkeley
03010201-080	Wando River	Charleston
03010202-070	Charleston Harbor	Charleston

Water Quality Parameter Not Complying With Criteria

The parameter of concern is dissolved oxygen. Information from DHEC=s ambient water quality monitoring stations in the Cooper River, Charleston Harbor, and the Wando River indicate that, with the exception of station MD-115 (Wando River @ SC 41), these waters do not meet the criteria to be considered impaired for dissolved oxygen when monthly data is compared to Section 303(d) criteria. However, continuous monitoring conducted by USGS shows that many portions of the system experience dissolved oxygen levels below applicable water quality criteria during the critical, high temperature periods for which wasteload allocations are developed. This is considered a natural phenomenon further impacted by point source discharges. In such cases, the 0.1 Rule applies, and this TMDL is being developed to determine the loading of oxygen demanding substances that can be allowed consistent with this rule.

Waterbody Classifications

The Tail Race Canal, the West Branch of the Cooper River, and the East Branch of the Cooper River are classified Freshwaters (FW) from Pinopolis Dam to the junction of the East and West Branches of the Cooper at a point approximately thirty miles above the junction of the Ashley and Cooper Rivers, commonly called the ATee.@ The remaining portion of the Cooper River below the specified point is classified SB as is Charleston Harbor. The Wando River is classified Shellfish Harvesting from its headwaters to a point approximately 2.5 miles above its confluence with the Cooper River. From this point to the Cooper River, it is classified SA.

Freshwaters are:

AFreshwaters suitable for primary and secondary contact recreation, and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora. Also suitable for industrial and agricultural uses.@ (R.61-68)

SB waters are:

ATidal saltwaters suitable for primary and secondary contact recreation, crabbing and fishing except for harvesting of clams, mussels or oysters for market purposes or human consumption. Also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.@ (R.61-68)

SA waters are:

ATidal saltwaters suitable for primary and secondary contact recreation, crabbing and fishing except harvesting of clams, mussels, or oysters for market purposes or human consumption and uses listed in Class SB. Also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.@ (R.61-68)

Shellfish Harvesting waters are:

ATidal saltwaters protected for shellfish harvesting and uses listed in Class SA and Class SB. Suitable for primary and secondary contact recreation, crabbing and fishing. Also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.@ (R.61-68)

Dissolved Oxygen (DO) Criteria

Cooper River:	
From Pinopolis Dam to 30 miles above the junction of the Ashley and Cooper Rivers	FW - Daily average of 5.0 mg/l with a low of 4.0 mg/l
That portion below 30 miles above the junction of the Ashley and Cooper Rivers	SB - Not less than 4.0 mg/l
Wando River:	SA and SFH - Daily average of 5.0 mg/l with a low of 4.0 mg/l
Charleston Harbor	SB - Not less than 4.0 mg/l

TMDL TECHNICAL BASIS

Target Identification

As discussed above and in Appendix B, Charleston Harbor, the Cooper River, and the Wando River are considered to be water quality limited for oxygen demanding substances due to naturally occurring, low dissolved oxygen concentrations under critical, summertime conditions. As such, the 0.1 Rule applies and the water quality target for this TMDL is a depression of no more than 0.1 mg/l of dissolved oxygen. The pollutant of concern is biochemical oxygen demand, both carbonaceous and nitrogenous, the combination of which can be expressed as ultimate oxygen demand (UOD). The UOD is calculated using Equation 1 or Equation 2 below, depending on whether the effluent monitoring data are in the form of (1) flow and concentration or (2) load. The TMDL will be in terms of UOD, based on the waterbody=s ability to assimilate oxygen demanding substances from point source dischargers without exceeding the allowable 0.1 mg/l deficit. Actual NPDES permit limits will include a numeric limit for UOD and at a minimum require monitoring and reporting for the carbonaceous and nitrogenous components of the UOD, BOD5 and ammonia. In some cases, NPDES permitting may require additional numeric limits for the carbonaceous and/or nitrogenous components for reasons unrelated to the TMDL. NPDES permitting may also substitute CBOD5 for BOD5, depending on which effluent test method is used by the permit holder.

$$UOD = Qd*8.34*(F\text{-}Ratio*BOD5 + 4.57*NH3\text{-}N) \quad \ldots\ldots\ldots \quad (1)$$

where UOD = ultimate oxygen demand in lbs/day,
Qd = effluent flow in MGD,
8.34 = units conversion factor,
F-Ratio = ratio of ultimate biochemical oxygen demand to five-day biochemical oxygen demand,
BOD5 = five-day biochemical oxygen demand in mg/L,
4.57 = units of oxygen consumed per unit of NH3-N oxidized,
NH3-N = ammonia nitrogen in mg/L.

$$UOD = F\text{-}Ratio*BOD5 + 4.57*NH3\text{-}N \quad \ldots\ldots\ldots \quad (2)$$

where UOD = ultimate oxygen demand in lbs/day,
F-Ratio = ratio of ultimate biochemical oxygen demand to five-day biochemical oxygen demand,
BOD5 = five-day biochemical oxygen demand in lbs/day,
4.57 = units of oxygen consumed per unit of NH3-N oxidized,
NH3-N = ammonia nitrogen in lbs/day.

The F-Ratio was assigned depending on the characteristics of the wastewater. A value of 1.5 was used for the domestic wastewater treatment plants, 3.0 was used for the industrial wastewater sources, and 4.0 was used for the paper mill effluent.

Point Sources

There are numerous public and private entities permitted to discharge wastewater to the Charleston Harbor, Cooper River, and Wando River system under the National Pollutant Discharge Elimination System (NPDES). These permits regulate the discharge of industrial and domestic wastewater, stormwater and cooling water. Twenty-five discharges are included in the model domain. Eleven of these were included in the model in an effort to consider all potential sources; however, they were not included in the allocation process due to their insignificant impact on DO. The remaining fourteen dischargers were considered significant contributors of oxygen demanding substances and were included in the TMDL calculator and TMDL allocation. These are listed in Table 1, along with their current UOD and flow. Discharger locations are shown in Figure 2. Note that in Table 1, flows are estimated for industrial dischargers since they are traditionally limited by loading without specific flow limits and that UOD for some dischargers is estimated since all current permits do not include specific limits for ammonia. Also, note that the City of Hanahan (NPDES SC0021041) is now inactive and, while in the calculator, has not been given an allocation. Subsequent to receipt of the COG recommended allocations, the S.C. Ports Authority (NPDES SC0021385) discharge was found to be inactive. For consistency with the COG allocations, it is included in the calculator; however, its allocation is insignificant.

Non-Point Sources

It is recognized that there are significant non-point sources of many types of pollution, both man-induced and natural, to the Charleston Harbor system. This TMDL is focusing on compliance of point sources with the 0.1 Rule included in R.61-68. As such, non-point sources of pollution are considered in this analysis only as they impact boundary and background conditions in the modeling effort. EPA has concurred that, given the current modeling for this system and the identified target for this analysis, a dry weather, critical condition TMDL, including only point sources, is appropriate (Appendix A). Non-point sources of pollution will be considered in any

Figure 2. Discharge Locations

Table 1
Existing NPDES Permitted Loadings

Discharge	NPDES	Flow	CBOD5		CBODU		NH3		UOD	Percentage
	Permit Number	mgd	mg/L	lbs/day	mg/L	lbs/day	mg/L	lbs/day	lbs/day	of Total
Monks Corner WWTF	SC0021598	1.6	30.0	400	45	600	20.0	267	1,820	0.978
Central BCW&SA	SC0039764	0.35	30.0	88	45	131	20.0	58	398	0.21
DAK	SC0026506	1.322	21.5	237	64	711	1.0	11	761	0.409
Bayer	SC0003441	5.65	31.7	1,492	95	4,476	6.3	295	5,824	3.13
City of Hanahan	SC0021041	0	0.0	0	0	0	0.0	0	0	0.00
BP	SC0028584	4.23	28.1	990	84	2,970	0.0	0	2,970	1.60
Lower BCW&SA	SC0046060	15.0	30.0	3,753	45	5,630	20.0	2,502	17,064	9.171
Westvaco	SC0001759	25.6	68.6	14,655	275	58,620	0.0	0	58,620	31.507
SC Ports	SC0021385	0.056	30.0	14	45	21	0.0	0	21.0	0.011
Daniel Island	SC0047074	0.5	5.0	21	8	31	1.0	4	50.3	0.027
North Charleston Sewer District	SC0024783	27	30.0	6,755	47	10,538	38.3	8,624	49,952	26.848
Plum Island WWTP	SC0021229	36	30.0	9,007	45	13,511	20.0	6,005	40,953	22.011
Center Street	SC0040771	3.7	30.0	924	45	1,386	20.0	617	4,206	2.261
Rifle Range	SC0040771	3	30.0	751	45	1,126	20.0	500	3,413	1.834
								Total	186,053	100.0

future modeling work for this system while the Department continues it efforts to address non-point sources through existing programs.

TMDL DEVELOPMENT

History of Model Development in the Charleston Harbor System

In the early 1990's, the South Carolina Coastal Council (now DHEC's Office of Ocean and Coastal Resource Management) initiated the Charleston Harbor Project (CHP), an interdisciplinary, comprehensive study of the Charleston Harbor system (CHS). A Charleston Harbor Modeling Group was formed to develop a monitoring and modeling plan for the CHS. One objective of the CHP was to develop a state-of-the-art water quality model to be provided to the DHEC for TMDL development. Another objective was development of a non-point source (NPS) water quality model. The NPS effort was completed for only a small urban watershed and did not provide the information needed to conduct dynamic, non-point source loading simulations. The CHP model workgroup included representatives from DHEC, SC Coastal Council, EPA (Region 4 and Office of Research and Development), USGS, Clemson University, and the University of South Carolina, among others.

The CHP model workgroup implemented a plan to develop separate one dimensional (1-D) water quality models for the rivers and tie them to a three dimensional (3-D) model of the harbor. Each of the river models was to have an overlapping segment with the harbor model so there would be continuity between the models. After initial data collection and several years of effort to set up a usable 3-D model, the project failed to produce results. Due to technical problems (the hydrodynamic and water quality models were never successfully linked) and model constraints, it was decided to proceed with a two dimensional (2-D) model for the harbor rather than the 3-D model originally proposed. Also, it was decided to use the Branch/Branched Lagrangian Transport Model (Branch/BLTM) modeling platform, rather than Water Quality Analysis Simulation Program (WASP), for the rivers. Ultimately, plans to model the harbor were dropped and the Cooper River Branch/BLTM model was extended to the Customs House and joined with the Wando River model. The major reasons why the CHP was not successful in developing a 3-D model of the Harbor were the models were too complex for the computers available at the time, the research was not successful in getting the selected hydrodynamic model to communicate with the water quality model, and the collection of physical and chemical data of the CHS was limited. Work by USGS, in conjunction with DHEC, continued on the less complicated 1-D Branch/BLTM models of the Cooper/Wando system and the Ashley River.

In the late 1990's, the Charleston Commissioners of Public Works (CPW) proposed a major new discharge for the Cooper River. After discussions with DHEC, CPW was concerned the Charleston Harbor Project model for the Cooper River would not be completed within their review time frame and that the Branch/BLTM model, which ended just downstream of the proposed discharge location, would not be adequate to evaluate their proposal. CPW proposed to hire a private consulting group, Applied Technology and Management, to develop a 3-D model for the entire system (similar to the original Charleston Harbor Project proposal) and provide this model to DHEC for TMDL development. This CPW effort, including collection of additional velocity, flow, and DO data, eventually came to be supported by the major discharges to the Cooper River.

A modeling workgroup was assembled by DHEC to review the two modeling efforts and make recommendations upon their applicability and use. The workgroup, composed of representatives from DHEC=s Bureau of Water, EPA Region 4, the S.C. Department of Natural Resources (SCDNR), DHEC=s Office of Ocean and Coastal Resources Management (OCRM), the USGS, the S.C. Coastal Conservation League (SCCCL), and ATM convened as the modeling progressed to provide technical guidance and recommend technical approaches. One of the main technical recommendations of the workgroup was to use a 2-D Water Quality Mapping and Analysis Package (WQMAP) model to represent the CHS. The WQMAP model domain is shown in Figure 3. This recommendation was based on computer capabilities available at the time, the complexity of the model and availability of data. It was impractical to run a 3-D model with "run times" that exceeded 3 days for regulatory purposes. In addition, a side-by-side model analysis by ATM demonstrated the 2-D model to be more conservative and, therefore, if used for

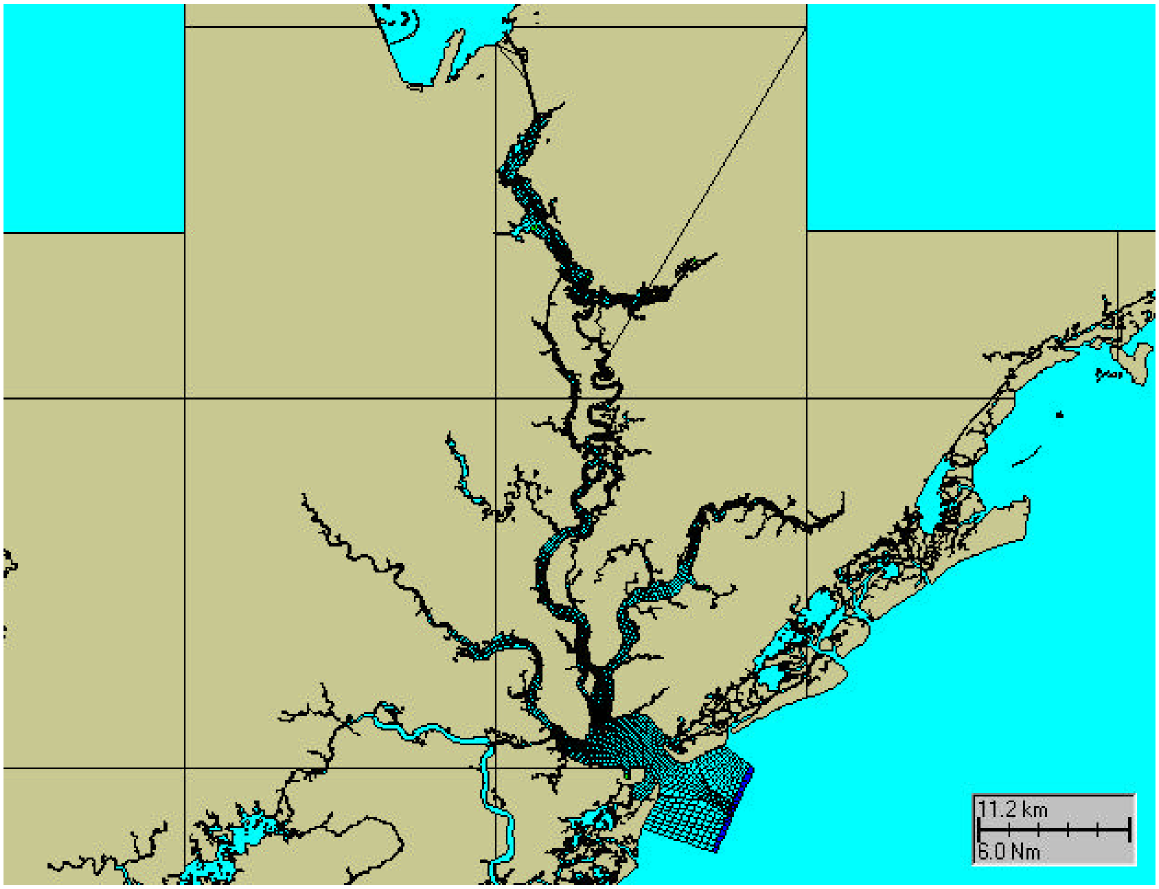

Figure 3. WQMAP Model Grid

regulatory purposes would be more protective of the environment. On the recommendation of the workgroup, DHEC decided to use the 2-D modeling approach for the estuary. It was also determined by the workgroup that the USGS Branch/BLTM model, which had significantly shorter run times than the 2-D model, could be utilized as a screening tool to make initial decisions, which could then be confirmed and refined using the ATM developed WQMAP model.

ATM, working for a group of major Cooper River dischargers, calibrated the 2-D model to data collected in 1996 and validated it to the 1993 data set. ATM then turned the model over to DHEC for use in TMDL development. DHEC used the 2-D model in conjunction with the USGS 1-D model to develop a draft TMDL for the Cooper River and Charleston Harbor that was placed on public notice in December of 2000. Details on the WQMAP model are included in the ATM reports "Development of a Waste Load Allocation Model within the Charleston Harbor Estuary, Part 1: Hydrodynamics and Mass Transport, January 1999" and ADevelopment of a Waste Load Allocation Model within the Charleston Harbor Estuary, Part 2: Water Quality, August 1999.@

Initial Draft TMDL

The calibrated USGS-developed BRANCH/BLTM and ATM-developed WQMAP models were modified to reflect the critical conditions appropriate for TMDL and wasteload allocation development (tide, temperature, background pollutant loading, etc.). Maximum allowable loadings for oxygen demanding substances, expressed as UOD, were determined for various segments of the Cooper River. Loadings varied from segment to segment with excess capacity identified in some upstream segments while the need for reductions of up to 92% were called for in some lower segments.

On December 15, 2000 the Department placed the draft TMDL for the Cooper River on 30-day public notice. In response to numerous requests for additional time to review and comment on the draft, the public comment period was extended to January 31, 2001.

Public Comment

Numerous comments were received by the Department on the proposed TMDL. While some were supportive of the TMDL, others questioned its legality, the economic impact of the required cuts in pollutant loading, and the technical analysis upon which the TMDL was based. Further, some asked for an independent review and evaluation of the modeling process by EPA. The comments received during the initial review resulted in significant modifications to the TMDL that are reflected in this document. A summary of the comments and the Department=s response is attached as Appendix C.

EPA Review

While the Department was confident in the overall TMDL analysis, legitimate concerns had been raised over model documentation and the Department=s inability to provide all model files upon which TMDL decisions were based. Understanding the overall implications of the proposed TMDL loadings and the regulated community=s desire for additional review, the Department requested that EPA Region 4 review the model to verify all loadings, rate coefficients, and model inputs. Further, EPA was requested to evaluate the modeling process and the WQMAP model application and draw conclusions concerning the validity of each. EPA agreed to conduct the review.

EPA began their review by obtaining the latest version of the WQMAP model and interface, along with a version of the Department=s TMDL model run, from ATM, the developer of the WQMAP application for the Charleston Harbor system. EPA determined that WQMAP run times on the faster computers available today were sufficiently short to negate the need for use of the BRANCH/BLTM as a screening tool. All WQMAP inputs were evaluated and corrections and updates made as appropriate. Inputs for bottom friction, wind kinetics, and marsh loadings were modified to ensure they were properly handled by the model. A particularly important modification was the inclusion of a revised nitrification rate. ATM had recommended the calibrated rate be lowered to reflect the removal of a major discharge of ammonia from the system; however, technical studies to determine the rate were not done prior to finalization of the initial draft TMDL. Lacking a technical justification for the change, the Department utilized the calibrated value. Subsequent to issuance of the initial draft TMDL, ATM provided EPA and the Department with a technically defensible nitrification rate, based on a new field study, which was then utilized in the model. With the exception of the four inputs mentioned above, the critical conditions selected by EPA for the predictive modeling are the same as those applied in the Department=s initial draft TMDL model runs. The EPA review process and the assumptions and methodology used by EPA in their certification of the 2-D WQMAP water quality component of the wasteload allocation model are described in detail in Appendix A.

Using the updated model and revised model inputs, EPA conducted multiple model runs to develop an understanding of and a level of confidence in the WQMAP model. Development of new post processors by ATM allowed the available deficit to be calculated on a volume weighted average basis for each segment, considered by EPA to be a more appropriate method, as opposed to the cross section average used in the original analysis. EPA determined there were two critical segments that were affected by all discharges to the system to one degree or another. Three scenarios were then run: a Ano load@ model run, a model run at loads approximating current permit conditions, and the loadings used in the Department=s initial draft TMDL. The model run using current permitted loadings resulted in a predicted DO deficit of 0.47 mg/l in the most critical segment, from the mouth of the Cooper River to Goose Creek. The run using loads used in the initial draft TMDL predicted a deficit of 0.075 mg/l in that segment; however, EPA=s runs included an effluent DO of 6 mg/l which was not included in the initial TMDL runs. When the effluent DO is removed from the EPA run, the predicted deficit with the original loadings approaches 0.1 mg/l, the allowable deficit.

EPA Conclusions and Recommendations

EPA concluded Athe 2-D WQMAP model used to develop the proposed TMDL for oxygen-demanding wastes for the Charleston Harbor System is a technically defensible model and is acceptable for calculating the wasteload allocations for point sources discharging to the Charleston Harbor System at non-wet weather critical conditions.@ As such, the model could be used to develop a TMDL for the typical high temperature, low flow conditions for which wasteload allocations are developed. EPA further concluded Athe resultant 2-D model is capable of examining the D.O. deficits caused by the point sources dischargers and comparing these results to the SCDHEC 0.1 mg/l allowable deficit D.O. Rule.@ A copy of the updated model used in the EPA analysis was provided to the Department.

TMDL Calculator

Through the model review process, EPA was able to develop an innovative approach for determining acceptable loadings to the Charleston Harbor system. Using the output from sequential model runs isolating the impact of each individual discharge, EPA developed a spreadsheet based ATMDL calculator@ which mimics the WQMAP model and predicts the dissolved oxygen deficit associated with any combination of loadings. Since it is spreadsheet based, the calculator allows scenario comparisons to be done almost instantaneously whereas individual WQMAP runs take several hours. A basic premise of the calculator, as indicated by the multiple model runs, is that there are two critical segments in the system: the lower portion of the Cooper River from Goose Creek to the mouth of the Cooper River and the upper portion of the harbor referred to by EPA as the Cooper/Wando estuary. Both segments are affected by all dischargers to the system to varying degrees. The calculator includes a weighting factor for each discharge which takes into account each discharger's location in the system and impact on the critical segment. The result is not a single available load for the system or a series of loads for the various model segments, as was the case in the initial draft TMDL. Rather, the calculator can predict a series of loadings, any of which can result in a deficit consistent with the 0.1 Rule. This allows a true watershed approach to TMDL development and allocation. Utilizing this tool, the loading can be optimized to most efficiently divide the available load among the many discharges to the system based on such factors as waste treatability, current treatment plant technology, and the costs associated with upgrading treatment at various plants throughout the system. The TMDL calculator was provided to the Department for use in developing a revised TMDL.

DHEC Model Review

The Department reviewed the work done by EPA, including the model and TMDL calculator. It was determined that the EPA modifications to the original model were appropriate and acceptable. The calculator was evaluated with multiple runs compared to actual model runs that include identical loadings. It was determined that the calculator was an acceptable tool for evaluating alternative scenarios provided final loadings were verified through actual WQMAP model runs.

Council of Governments Involvement

The local Berkeley/Charleston/Dorchester Council of Governments (COG) is a designated water quality planning agency. The COG, which has been very active throughout the Cooper River TMDL process, is responsible for allocating TMDL loadings among existing and proposed discharges. The COG was provided the TMDL calculator to assess alternatives and ultimately determine the final allocation of the available load. At their request and with Department approval, two minor modifications were made to the calculator: the previously combined Mt. Pleasant discharges were entered as separate discharges and the $CBOD_5$ to $CBOD_u$ ratio (F-ratio) for the Lower Berkeley plant was decreased to 1.5, a value consistent with other domestic dischargers. Working through a committee composed of local stakeholders, the COG determined an acceptable allocation of oxygen demanding substances of 57,521 lbs/day of ultimate oxygen demand. This is equivalent to an approximate 70% decrease from existing permitted loadings. The loading is based on the calculator inputs provided in Appendix D. Due to the complexity of the situation, the number of discharges involved, the conservative nature of the current 2 dimensional (2-D) model, recent advancements in model and computing abilities, and the impacts associated with implementation of the TMDL, the COG recommended a phased approach with an initial decrease in loading to the system to 78,125 lbs/day UOD, an approximate 60% cut from the existing permitted loading. This loading is based on the calculator inputs provided in Appendix D. The COG further recommended appropriate schedules of compliance be incorporated into NPDES permits implementing the TMDL loadings and agreed to coordinate on the development of a 3-D model for the system to verify Phase 2 reductions.

DHEC Verification of Proposed TMDL

Using the WQMAP model approved and provided by EPA, the Department has verified the proposed Phase 2 (final) loadings developed by the COG are consistent with the 0.1 Rule and as such are acceptable to the Department.

REVISED TOTAL MAXIMUM DAILY LOAD

Critical Conditions Loadings

Critical condition Phase 1 and Phase 2 TMDL loadings, based on the EPA updated model and the COG recommended allocations provided in Appendix D, are provided in Table 2.

Table 2
Proposed TMDL Loadings In Pounds/Day Ultimate Oxygen Demand

Phase 1 (Interim) Loadings	78,125
Phase 2 (Final) Loadings	57,521

Ultimate Oxygen Demand = Ultimate Carbonaceous BOD + Ultimate

Model scenarios and associated files are being placed on compact disk and will become part of the TMDL administrative record. Copies of the disk are to be provided to EPA, ATM and the COG for review. Since the WQMAP model is proprietary and cannot be run without special computer hardware unavailable to the general public, copies of the disk are not being distributed with all copies of the TMDL. Copies of the disk are available on request and the information included on the disk can be viewed at DHEC=s central office in Columbia.

Critical Conditions

Water quality models are calibrated and validated to conditions existing during field sampling events. These conditions may or may not be the same as the critical conditions for which wasteload allocations and TMDLs are developed. Based on the information obtained during the sampling events and the understanding of the system being modeled that is generated through the study process, model inputs and rates are adjusted so that the model accurately simulates a given study period. When a model does this, it is said to be calibrated. When, with only minor adjustments, the model can accurately predict water quality under different conditions (flow, temperature, loading, etc.) the model is said to be validated. It is then that the model is considered a good tool for predicting discharger impacts and can be modified to reflect the critical conditions State and Federal regulations require to be used for TMDL and wasteload allocation development. Critical conditions were determined according to the Tetra Tech document, developed under contract to EPA, included at Appendix E. Water quality parameters were set to represent 75/25 percentiles, average spring and neap tidal conditions were evaluated with fresh water inflow set to approximate a 7Q10 recurrence, and algal processes were turned off.

EPA reviewed the critical conditions and modeling parameters used in the draft TMDL as part of their evaluation of the WQMAP model of the Charleston Harbor system. As discussed above and in Appendices A and C, the critical condition and modeling inputs used in the EPA recommended model are the same as in the DHEC critical condition model runs with the exception of the nitrification rate used, the inclusion of revised bottom friction coefficients and updated wind kinetics and marsh loadings. The critical condition values and model inputs used in the TMDL model runs are included in EPA=s Charleston Harbor TMDL Modeling Report

(Appendix A), pages 2-18 through 2-23.

Seasonality

Consideration of seasonality is required when determining TMDL limits. For this TMDL, the critical period is considered to be the low flow, high temperature conditions associated with summer and early fall. This is considered to be the time of greatest potential stress to the system due to low oxygen concentrations. Calibration model inputs are adjusted to reflect these conditions which approach, though do not reach, worst case. As discussed above, the critical conditions included in the model are consistent with EPA recommendations (Appendix E) and have been verified by the EPA model review (Appendix A).

In recognition of the greater assimilative capacity associated with colder temperatures, NPDES permits issued for dischargers impacted by this TMDL may include seasonal limits for the months November through February. Since the loadings determined to be appropriate for winter conditions are not based on the critical conditions of the TMDL, they will not be made a part of the TMDL. Rather, they will be incorporated as wasteload allocations in the NPDES permits issued to dischargers to the system.

Margin-of-Safety

TMDLs are required to include a margin-of-safety (MOS) to account for uncertainty in the technical evaluation. This margin-of-safety can be explicit, as when a percentage of the TMDL loading is reserved as a MOS and not allocated, or it can be implicit, as when conservative modeling assumptions are used to provide a MOS. For this TMDL, an implied MOS is utilized. This is achieved through use of conservative modeling assumptions, input of all point sources at permitted flows and loadings, and use of critical conditions such as 75th/25th percentile values of measured water quality parameters, evaluation at spring and neap tidal conditions, and inclusion of freshwater inflows approximating 7Q10 conditions. Use of the implied MOS for this TMDL has been accepted by EPA as indicated in their report AReview of the *Review of Key Model Inputs and Sensitivity Analysis for TMDL Simulations using the two-dimensional WQMAP Water Quality and Hydrodynamic model developed for the Charleston Harbor System*, EPA Region 4" included as Appendix F.

IMPACT ON ENDANGERED SPECIES

Application of the 0.1 Rule will allow a de minimis lowering of dissolved oxygen levels in the Charleston Harbor System. Under critical conditions, the TMDL will allow a lowering of dissolved oxygen by approximately one tenth of one part per million below natural conditions. This will protect the short nosed sturgeon, the known aquatic endangered species in the area, as well as for aquatic life uses of all other species, as related to dissolved oxygen.

ADDITIONAL MODELING AND ANALYSIS

The Berkeley-Charleston-Dorchester Council of Governments (COG) has, through use of the EPA developed TMDL calculator, determined final loadings consistent with the 0.1 Rule. The Department has agreed to implement reductions in two phases to allow development of additional technical information on the Charleston Harbor system. Through the COG, area dischargers have committed to implementing Phase 1 loadings to demonstrate reasonable progress toward achieving compliance with applicable water quality standards within the current reissuance cycle of NPDES discharge permits. The COG has proposed additional study and modeling work during Phase 1 permits to verify the specific reductions for Phase 2. The implementation plan included below provides time for additional study and modeling.

Dischargers to the system, through the COG, have committed to developing a 3-D hydrodynamic and water quality model of the Charleston Harbor system for use by the Department and EPA in verifying or refining final TMDL limits. The Department has agreed to coordinate with the COG and a private consultant selected and compensated by the COG in this effort and has provided an outline of requirements for the new modeling effort. These include, but are not limited to, the following. A study plan describing all aspects of the data collection and modeling efforts would have to be approved by the Department and EPA. The modeling platform would have to be non-proprietary and acceptable to the Department and EPA. The model would have to be comprehensive in scope covering the harbor and its tributaries and have to evaluate dry and wet weather critical conditions including wet weather non-point source loads. The model would have to reflect actual system bathymetry and be able to simulate changes resulting from navigation and or port modifications. The model would have to be capable of evaluating absolute dissolved oxygen concentrations- not just the change associated with a specific load. The model would have to be appropriately calibrated and validated with appropriate sensitivity analyses performed. When provided to the Department, the model package would have to include adequate post processing capability for data analysis. Training in use of the chosen modeling platform would have to be provided to DHEC staff with appropriate technical assistance provided to the Department throughout the modeling effort and TMDL development.

An approvable, calibrated model, along with appropriate documentation, must be provided to the Department within three years of issuance of the Phase 1 permits. It is important that the entire process of model development and review take no more than 3 years so there will be sufficient time remaining in the permit cycle to provide public participation of any revised TMDL and to develop new limits for the next permitting cycle.

IMPLEMENTATION PLAN

As a dry weather, critical conditions TMDL dealing with point sources, the loadings identified above will be implemented through limits placed on NPDES permits issued to dischargers in the system. Wasteload allocations for existing and proposed dischargers will be based on the COG proposed critical condition allocations and DHEC determined winter condition allocations (November through February) and will be included in permits as monthly average limits. In addition to monthly average limits, appropriate daily maximum and weekly average limits may be included in permits per SC Regulation 61-9. These permits, most of which are currently expired, are to be reissued for a period of 5 years. Dischargers will be required to achieve compliance with Phase 1 NPDES limitations, as identified in Appendix D, in accordance with appropriate individual compliance schedules where justified. In the absence of additional information to be developed through use of the proposed 3-D model, final limits, as provided above and with allocations as proposed by the COG, will be incorporated in NPDES permits to be issued at the close of the 5-year permit period. Appropriate compliance schedules, where justified, will be included in permits.

Upon completion of the 3-D modeling effort, DHEC will use the model to determine load requirements, including WLAs, consistent with water quality standards. If appropriate based on the information developed by the 3-D modeling effort, the TMDL will be modified, subject to all requirements of relevant State and Federal regulations.

Upon reissuance of NPDES permits at the end of the initial 5-year permit, limits will be established as necessary to conform to requirements of the Phase 2 loadings identified above or to a revised TMDL resulting from the proposed 3-D modeling. In either case, appropriate compliance schedules, where justified for achieving any more stringent limits, will be included.

TMDLs are generally considered to be a defined maximum loading for a waterbody. Because of the watershed approach used for the Charleston Harbor system, the TMDL can be any combination of loadings from the many dischargers to the system that is consistent with the 0.1 Rule. The loadings identified above and the allocations recommended in Appendix D, which are to be included in NPDES permits, are but one combination that would satisfy this goal. Subject to COG and DHEC approval, NPDES permits may be modified to reflect trading of UOD between dischargers provided the resulting loads comply with the goal of the TMDL.

This TMDL is developed to ensure point source compliance with the 0.1 Rule provision of R.61-68. Though non-point sources of pollution are not directly addressed by either Phase 1 or Phase 2 of the TMDL, the Department will continue to address these sources of pollution through the NPDES stormwater permitting program, the 401 Water Quality Certification program, the State Stormwater Management & Sediment Reduction Act, the S.C. Non-point Source Management Plan, and other programs as available to control non-point source inputs to the watershed thereby helping to ensure water quality is maintained or enhanced. The proposed 3-D modeling effort is to consider wet weather conditions and load allocations, as well as wasteload allocations, for the system

REFERENCES

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APPENDICES

APPENDIX A

U.S. ENVIRONMENTAL PROTECTION AGENCY MODELING REPORT

CHARLESTON HARBOR TMDL MODEL REVIEW
ASHLEY COOPER RIVER SYSTEM
JIM GREENFIELD, EPA REGION 4
Final Review Package April 2002

Mr. Alton Boozer May 2, 2002

Chief, Bureau of Water

South Carolina Department of Health

And Environmental Control

2600 Bull Street

Columbia, South Carolina 29201

Dear Mr. Boozer:

I have completed my model review of the 2D WQMAP for the Charleston Harbor System as you requested. The history of the modeling project and my review efforts are described in the attached report.

During 2001, EPA and SCDHEC made a number of model runs with an updated version of the WQMAP model for the Charleston Harbor System to obtain TMDL outputs, and to develop an understanding and a level of confidence in the WQMAP model. EPA's conclusion is that the 2D WQMAP model used to develop the proposed TMDL for oxygen-demanding wastes for the Charleston Harbor System is a technically defensible model and is acceptable for calculating the wasteload allocations for point sources discharging to the Charleston Harbor System at non-wet weather critical conditions. The critical conditions selected by EPA for the predictive modeling are the same as those applied in SCDHEC's model except for adjustment of the nitrification rate, the inclusion of the bottom friction and the assurance that the wind kinetics and marsh loadings were included in the critical condition model.

If you have questions regarding the attached report on my model review, or if I can be of further assistance, please call me at 404/562-9238.

Sincerely,

James Greenfield,

Senior TMDL Modeler

Water Management Division

Charleston Harbor TMDL Model Review
Ashley Cooper River System
Jim Greenfield, EPA Region 4

Final Review Package April 2002

BACKGROUND:

The Charleston Harbor System is located along the southern coast of South Carolina. The System extends over approximately a 1,200 square mile region and consists of 3 primary tributaries: the Cooper, Wando, and Ashley Rivers. Historically, the Ashley, Wando, and Cooper Rivers were all tidal sloughs with limited freshwater inflow and extensive tidal marshes. Presently, the Ashley and Wando Rivers remain tidal sloughs with varying levels of urban development along their reaches. Over its history, the Cooper River has undergone extensive anthropogenic changes. In the 17th and 18th centuries, rice plantations existed along the banks of the Cooper River with extensive diked fields. Remnants of these fields can be seen above the "Tee" where the Cooper River splits into the East and West Branches.

In the 1930s, the Santee-Cooper Project created 2 freshwater lakes by diverting the flows from the Santee River and using the naturally high topographic relief at the upper end of the Cooper River. Two dams that generated hydroelectric power were created: the Wilson Dam which discharged to the Santee River, and the Pinopolis Dam which discharged to the upper Cooper River. The flows diverted to the west branch of the Cooper River altered it from a tidal slough to a riverine system with a significant freshwater discharge (approximately 15,600 cfs average). The increased freshwater discharge with its associated sediment load created problems in the lower harbor. In 1985, a portion of the freshwater inflow to the Cooper River was diverted back to the Santee River and the freshwater flows were reduced to an average of 5,000 to 6,000 cfs.
The primary mechanism providing hydrodynamic forcing to the system are the tides propagating into the Harbor through the Charleston Harbor Entrance. The inlet, which connects the Charleston Harbor to the Atlantic Ocean, is approximately 1 mile wide. The

channel is jettied out a distance of 3 miles from the entrance. Portions of the jetties are emergent at low tide and submerged at high tide while the rest remain emergent throughout the tidal cycle. The tides range from 5.09 feet Mean Low Water (MLW) on average up to 5.90 feet MLW during spring tide conditions. These tides extend and amplify up the Wando and Ashley Rivers. On the Cooper River, the tides are felt as high as at the Pinopolis Dam, but there is significant damping of the tidal wave in the area around the Tee and above in the East and West Branches of the Cooper River.

The primary mechanism providing hydrodynamic forcing to the system are the tides propagating into the Harbor through the Charleston Harbor Entrance. The inlet, which connects the Charleston Harbor to the Atlantic Ocean, is approximately 1 mile wide. The channel is jettied out a distance of 3 miles from the entrance. Portions of the jetties are emergent at low tide and submerged at high tide while the rest remain emergent throughout the tidal cycle. The tides range from 5.09 feet Mean Low Water (MLW) on average up to 5.90 feet MLW during spring tide conditions. These tides extend and amplify up the Wando and Ashley Rivers. On the Cooper River, the tides are felt as high as at the Pinopolis Dam, but there is significant damping of the tidal wave in the area around the Tee and above in the East and West Branches of the Cooper River.

A significant component of the hydraulics within the Charleston Harbor System is the extensive tidal marshes that line the three tributaries and the harbor area. Fed by small feeder creeks, these areas provide extensive inter-tidal exchange and storage of water. Additionally these inter-tidal marsh areas provide a mechanism for exchange of nutrients and oxygen demanding material with the adjacent receiving waters. Another significant water storage feature is the former rice fields that line the East and West branches of the Cooper River above the “tee” (see figure 1-1). Although flow within the East and West Branches is predominantly directed along the main channels, these large areas fill and drain off of the main channel and draw a significant volume of water up the Cooper River. This large exchange through the restricted area of the “tee” creates very high velocities along the upper portions of the Cooper River. Velocities in this area were measured as high as 4 to 5 knots. Additionally, a rather rapid damping of the tidal wave occurs in this region with an associated set-up above the “tee”. This is a direct function of the surface area filled above the “tee” and the propagation of the tidal wave along the winding main channel of the East and West Branches of the Cooper.

CHARLESTON HARBOR MODELING HISTORY:

In the early 1990's, the South Carolina Coastal Council (now SCDHEC's Office of Ocean and Coastal Resource Management) initiated the Charleston Harbor Project (CHP), an interdisciplinary, comprehensive study of the Charleston Harbor system (CHS). One objective of the CHP was to develop a state of the art water quality model to be provided to the SCDHEC for TMDL development. A Charleston Harbor Modeling Group was formed to develop a monitoring and modeling plan for the CHS. This was to include development of a non-point source water quality model. The workgroup included representatives from SCDHEC, SC Coastal Council, EPA Region 4 and ORD-EPA, USGS, Clemson University, the University of South Carolina among others.

The CHP workgroup implemented a plan to develop separate models for the rivers and tie them to a three dimensional (3-D) model of the harbor. Each of the river models was to have an over lapping segment with the harbor model so there would be continuity between the models. After initial data collection and several years of effort to set up a usable 3-D model, the project failed to produce results. The non-point source component was only completed for a small urban watershed and the hydrodynamic and water quality models were never successfully linked. Due to technical problems and model constraints, it was decided to go with a 2-D (TRIM) model for the harbor rather that the 3-D (ECOM-SI) model originally proposed. Also, it was decided to use the Branch/BLTM modeling platform, rather than WASP, for the rivers. Ultimately, plans to model the harbor were dropped and the Cooper model was extended to the Customs House and joined with the Wando River model. The major reasons why the CHP was not successful in developing a 3-D model of the Harbor were the models were too complex for the computers available at the time, the research was not successful in getting the selected hydro model to communicate with the water quality model, and the collection of physical and chemical data of the CHS was limited. Work by USGS, in conjunction with SCDHEC, continued on the less complicated 1-D Branch/BLTM model of the Cooper/Wand and Ashley Rivers.

In the late 1990's, the Charleston Commissioners of Public Works (CPW) proposed a major new discharge for the Cooper River. After discussions with SCDHEC, CPW was concerned the Charleston Harbor Project model for the Cooper River would not be completed within their review time and that the model, which ended just downstream of the proposed discharge location, would not be adequate to evaluate their proposal. CPW proposed to hire a private consulting group (Applied Technology and Management, ATM) to develop a 3-D model for the entire system, similar to the original Charleston Harbor Project proposal, and provide this model to SCDHEC for TMDL development. This DPW effort, including collection of additional velocity, flow and DO data, eventually came to be supported by the major discharges to the Cooper River.

A modeling workgroup was assembled by SCDHEC to overview the 2 modeling efforts and make recommendations upon their applicability and use. The workgroup, composed of representatives from SCDHEC Bureau of Water, EPA Region IV, the S.C. Department of Natural Resources (SCDNR) SCDHEC Office of Ocean and Coastal Resources Management (OCRM), the U.S. Geologic Survey (USGS), the S.C. Coastal Conservation League (SCCCL), and Applied Technology and Management convened as the modeling progressed to provide technical guidance and recommend technical approaches. One of the main technical recommendations of the workgroup was to use a 2-D WQMAP model to represent the CHS. This recommendation was based on computer capabilities available at the time, the complexity of the model and availability of data. It was impractical to run a 3-D model with "run times" that exceeded 3 days for regulatory purposes. In addition, a side-by-side model analysis by ATM demonstrated the 2-D model to be more conservative and, therefore, if used for regulatory purposes would be more protective of the environment. On the recommendation of the workgroup, SCDHEC decided to use the 2-D modeling approach for the estuary. It was also determined by the workgroup that the USGS Branch/BLTM model, which had significantly shorter run times than the 2-D model, could be utilized as a screening tool to make initial decisions, which could then be confirmed and refined using the ATM model.

Based on EPA's recent experience in other estuaries, a 3-D model is typically necessary to represent the complexities of the dynamics of dissolved oxygen. While a 3-D model may have been more appropriate for the Charleston Harbor System, it is EPA's conclusion that the SCDHEC 2-D model is adequate and can be used to make a TMDL decision as long as the limitations and constraints of the model are acknowledged. The SCDHEC 2D water quality model has been designed appropriately within its capabilities to accurately evaluate the net deficit of dissolved oxygen associated with prescribed anthropogenic discharges to the system. The model has been designed to perform adequately under a 24-hour average, which is the appropriate time scale for assessing the net deficit of dissolved oxygen according to the State's water quality standards.

The CH Discharge Group's consultant, ATM, calibrated the 2D model to data collected in 1993 and 1996. ATM then turned the model over to SCDHEC for use in TMDL development. SCDHEC used the 2-D model in conjunction with the USGS 1-D model to develop the TMDL for Cooper River and Charleston Harbor. The State used the USGS 1-D model to develop the TMDL for Ashley River. Details on the model are included in the ATM report "Development of a Waste Load Allocation Model within the Charleston Harbor Estuary", January 1999.

SCDHEC TMDL PROPOSAL

On December 4, 2000, SCDHEC proposed a Total Maximum Daily Load for oxygen – demanding substances for the Charleston Harbor System using the 1993 and 1996 calibrated Charleston Harbor Cooper River models developed by Applied Technology Management (ATM) Consultants.

During the public comment period, the Charleston Harbor Discharge Group raised the following questions and concerns regarding SCDHEC's modeling approach:

- The TMDL model runs could not be supplied or reproduced by SCDHEC;
- Concern that the bottom friction in the TMDL runs was apparently set to a constant for the whole system.
- Concern that loadings from the marshes were not used in the TMDL runs. This would impact water storage and the resultant velocity and currents and the TMDL results.
- Were the wind speed was incorporated in TMDL run.
- Was the algae component was on or off during the TMDL run.

- Was the nitrification rate used in the model appropriate for the estuary system if the high ammonia discharge is removed as allocated in the TMDL.

Based on the concerns raised by this major stakeholder group, EPA Region 4 and SCDHEC revised the modeling approach to address the technical concerns.

EPA'S REVIEW AND ASSESSMENT OF THE SCDHEC WQMAP MODEL

EPA was asked in early 2001 to assess the SCDHEC'S 2D WQMAP model of the Charleston Harbor System, update and incorporate any necessary changes, and to provide a finding as to whether the 2D model approach is appropriate for TMDL development. EPA worked collaboratively with SCDHEC during 2001 to enhance the application of the 2-D WQMAP model by correcting application errors and resolving internal model problems. One of the enhancements included converting the previous Version 3 model runs to run under a newer version of the model. WQMAP Version 4 was released in September 2001. This version has the same solution techniques as Version 3, but has a more updated and less confusing interface that contributes less to "user" mistakes. The conversion process took a significant amount of time because of the "learning curve" especially regarding the interface and output abilities of the newer version.

During this time, ATM updated the 1993 and 1996 water quality calibrations and provided the model runs to EPA and SCDHEC. (A draft calibration report is in preparation.) EPA and SCDHEC worked with Harbor Group's consultant, ATM, to develop a "clean" critical condition TMDL model template that resolved most of the Harbor Group's modeling concerns raised during the public comment period.

Over the past months, EPA and SCDHEC made a number of CHS WQMAP model runs to obtain TMDL outputs, and to develop an understanding and a level of confidence in the model. EPA's conclusion is that the 2 dimensional Cooper River model used in the development of the TMDLs is a technically defensible model and is acceptable for calculating point source TMDLs at non-wet weather critical conditions. The initial data collection did not include sufficient information to develop a model that reflects absolute D.O. values. However, the resultant 2-D model is capable of examining the D.O. deficits caused by the point source discharges and comparing these results to the SCDHEC 0.1 mg/l allowable deficit D.O. rule.

Critical conditions and Model Parameters used in EPA's Revision to the WQMAP Model

EPA reviewed the critical conditions and modeling parameters used in the draft TMDL, utilized the parameters that were appropriate and modified/updated the parameters that were not appropriate. The final values used are as follows:

1. The basic internal modeling parameters and kinetics, such as the CBOD removal rate, SOD rate, reaeration rate, etc., used by SCDHEC in the critical condition modeling are the same values for these parameters and kinetics used in the original ATM calibration model.

2. The nitrification rate used was 0.035/day rate based on long-term BOD studies conducted by ATM in Summer 2001 and confirmed by EPA review of the data and analysis. (An ATM report is being prepared.) A rate of 0.3/day, initially proposed by ATM, was applied in the SCDHEC model based on the presence of a high ammonia point source discharge in the North Charleston area and resultant high stream ammonia concentrations. The high ammonia point source is predicted to be or has been eliminated; therefore, EPA adjusted the nitrification rate for the predictive model. (Note: The original 0.3/day rate is an appropriate rate for model calibration purposes.)

3. The modeling recommendations outlined in the 1998 Tetra Tech document "Review of the South Carolina Dynamic Modeling Applications for Dissolved Oxygen" were used for boundary condition inflows and D.O., BOD and nitrogen concentrations. The SCDHEC original inputs, the 7Q10 tributary inflows and the 75 percentile of the summertime pollutant concentrations and the 25 percentile of the headwater summertime dissolved oxygen concentrations is a viable and defensible procedure.

4. The selection of the 3,010 cfs weekly minimum upstream flow from Pinopolis Dam based on historic record is an appropriate assumption.

5. The approach applied for the critical tidal period was the theoretical water-surface-elevation-time-function at the ocean boundary over a time period that included a mean spring tide and a mean neap tide is an appropriate assumption.
6. NPDES permitted loads were used which is a standard predictive modeling convention.
7. The algal components were not incorporated in the WQMAP model.
8. The wind kinetics were not incorporated in the WQMAP model.
9. The marsh loadings were incorporated the WQMAP model.
10. The calibration runs had a variable bottom friction that was characteristic of the system. TMDL runs used this calibrated bottom friction file.
11. The wastewater D.O. component, which represents an effluent D.O. of 6 mg/l, added an 0.025 mg/l of D.O. to the system, may not have been included in the SCDHEC TMDL model. Based on conversation with SCDHEC technical staff, the original SCDHEC TMDL model runs may not have include a wastewater D.O. component.

In conclusion, the critical conditions selected by EPA for the predictive modeling are the same as those applied in SCDHEC's model except for adjustment of the nitrification rate, the inclusion of wastewater D.O. component, the inclusion of the bottom friction and the assurance that the wind kinetics and marsh loadings were included in the critical condition model.

OTHER EPA RECOMMENDATIONS FOR MODELING APPLICATION

TMDL Target

The applicable water quality standards according to SCDHEC regulations are as follows;

- 4.0 mg/L minimum within the Ashley, the Cooper River below the "tee" and Charleston Harbor.
- 4.0 mg/L minimum with a daily average of 5.0 mg/L within the Cooper River above the "tee" and the Wando River. (The Wando is, depending on location, either Class SA or Class SHF (shellfish harvesting) with no

mention of a site specific standard therefore it has average 5 mg/l with low of 4 mg/l.)

Based upon analysis of historic data, SCDHEC has determined that the dissolved oxygen levels in critical areas of the Charleston Harbor System drop below the applicable water quality standards, without anthropogenic impacts. This indicates "naturally occurring" depressed dissolved oxygen levels in critical areas of the estuary under some conditions. Under these circumstances, Existing SCDHEC water quality standards regulations evaluate the anthropogenic impacts based upon an acceptable dissolved oxygen deficit of 0.1 mg/l. The existing water quality standard specifies the deficit is applied to a 24-hour average.

Based on the output of the previous WQMAP model, SCDHEC, with the concurrence of ATM and based on the limited post processors available, applied the 0.1 deficit calculation to cross-sections near or below dischargers. Based on recent experiences in other estuaries, EPA recommends using a volume-weighted approach for calculating the DO deficit by dividing the CHS into segments that are internally similar both physically and chemically. There are two critical segments in the Charleston Harbor System:

- Cooper / Wando estuary area – River Mile 4.2 to 6.3
- Mouth of Cooper River to Goose Creek – River Mile 6.3 to 13.7

All the discharger's loadings, in the Cooper River System, have an impact on these two critical segments and will be addressed by this TMDL model.

EPA MODELING RESULTS

The hydrodynamic and water quality modeling parameters, rates and assumptions for the EPA basic model are included in Appendix A. Copies of the model inputs and outputs are available on compact disk (CD) "EPA Region 4: Charleston Harbor Critical Condition Model, 03/18/2002".

EPA has developed three main modeling scenarios:

Scenario 1: "Natural Condition" - no point source loadings;

Scenario 2: Point sources at existing NPDES permit condition;

Scenario 3: SCDHEC proposed 12/4/2000 TMDL limit; and

For each scenario, each of the two critical segments' volume average delta D.O. (mg/l) value (Table 1) were compared to the alternative model results with the no load scenario. The two critical segments are:

- Cooper / Wando estuary area – River Mile 4.2 to 6.3
- Mouth of Cooper River to Goose Creek – River Mile 6.3 to 13.7

Table 1: Summary of D.O. Deficit and Related Point Source Loads

Scenario	Delta D.O. for Critical Segment Volume – RM 4.2 to 6.3	Delta D.O. for Critical Segment Volume – RM 6.3 to 13.7	Total Cooper River Point Source Loading (#/day)
No Load	--------------------------------	--------------------------------	0
NPDES Point Sources at Existing Limits	0.45 mg/l	0.47 mg/l	170,000
SCDHEC Original TMDL	0.073 mg/l	0.075 mg/l	48,900

Scenario 1: No Load:

No D.O. deficit and point source loadings removed.

Scenario 2: Loadings based on existing permit loads

NPDES Permitted Loads result in D.O. deficit of 0.47 mg/l

Discharger	Flow	CBOD5		f-ratio	CBODU			NH3			UOD	%
	mgd	mg/L	lbs/day		mg/L	Lbs/day	g/s	mg/L	lbs/day	g/s	lbs/day	of Total
North Charleston Sewer District	27.0	25.0	5629	1.5	37.5	8444	44.3	40.0	9008	47.3	49609	29.6
Westvaco	22.9	76.7	14655	4.0	306.9	58621	307.8	0.0	0		58621	34.7
Plum Island WWTP	36.0	22.5	6756	1.5	33.8	10133	53.2	10.0	3002	23.6	23850	14.1
Mount Pleasant	6	30.0	1501	1.5	45	2,252	11.8	8.0	400	2.1	4,081	2.4
Lower BCW&SA	15.0	30.0	3753	2.0	60.0	7506	39.4	20.0	2502	13.1	18940	11.2
Bayer	4.9	27.5	1120	3.0	82.4	3360	17.6	16.4	668	3.5	6413	3.8
Monks Corner WWTF	1.6	30.0	400	1.5	45.0	600	3.2	20.0	267	1.4	1820	1.1
Amoco	2.3	27.8	541	3.0	83.5	1623	8.5	0.0	0		1623	1.0
City of Hanahan	1.3	30	313	1.5	43.2	469	2.5	20	209	1.09	1422	0.8
Dupont	1.3	20	221	3.0	60	662	3.5	04.0	44	0.23	863	0.5
Central BCW&SA	0.4	30.0	88	1.5	45.0	131	0.7	20.0	58	0.3	398	0.2
Texaco	0.2	30.0	48	1.5	45.0	71	0.4	20.0	32	0.2	216	0.1
Koch	0.1	30.0	20	1.5	45.0	30	0.2	20.0	14	0.1	92	0.1
SC Ports	0.1	30.0	14	1.5	45.0	21	0.1	20.0	9	0.0	64	0.0
C.R. Bard	0.2	14.1	23	1.5	21.1	34	0.2	0.0	0		34	0.0
RM Engineered	0.2	10.0	19	1.5	15.0	29	0.2	0.0	0		29	0.0
Detyens Shipyard	0.0	30.0	6	1.5	45.0	9	0.0	20.0	4	0.0	28	0.0
Daniel Island WWTP	0.3	5.0	10	1.5	7.5	16	0.1	1.0	2	0.0	25	0.0
SCE&G/Wms. Station	0.0	30.0	4	1.5	45.0	6	0.0	20.0	3	0.0	17	0.0
Girl Scout Council	0.0	30.0	3	1.5	45.0	5	0.0	20.0	2	0.0	14	0.0
Jeffries General Station	0.0	30.0	2	1.5	45.0	2	0.0	20.0	1	0.0	7	0.0
Amerada Hess, North	0.1	10.0	4	1.5	15.0	7	0.0	0.0	0		7	0.0
Cainhoy Elementary Packaging	0.1	5.0	3	1.5	7.5	5	0.0	0.0	0		5	0.0

Scenario 3: SCDHEC 12/4/2000 Draft TMDL Loads

Point source loads of approximate 47,500/day UOD resulted in the critical segment volume D.O. deficit of 0.075 mg/l using the updated model and the original S.C. distribution of the point source loads. Based on conversation with SCDHEC technical staff, the original SCDHEC TMDL model runs may not have included a wastewater D.O. component. The wastewater D.O. component, which represents an effluent D.O. of 6 mg/l, added an 0.025 mg/l of D.O. to the system. Therefore the original SCDHEC TMDL, without the wastewater D.O. component, had a D.O. deficit of 0.1 mg/l.

Discharger	Flow	CBOD5		f-ratio	CBODU			NH3			UOD	%
	mgd	mg/L	lbs/day		mg/L	Lbs/day	g/s	mg/L	lbs/day	g/s	lbs/day	of Total
North Charleston Sewer District	27.0	5.5	1238	1.5	9.0	1932	10.1	1.7	383	2.0	3681	7.8
Westvaco	22.9	11.3	2150	4.0	45	8600	45.15	0.0	0		8600	18.1
Plum Island WWTP	36.0	15	4504	1.5	23	6755	10.1	5.0	1501	7.9	13616	28.6
Mount Pleasant	5.2	58.0	2,515	1.5	87	3,773	19.8	26.5	1,149	6.0	9025	18.5
Lower BCW&SA	15.0	7.7	963	2.0	15	1927	10.1	1.5	188	1.0	2784	5.9
Bayer	4.9	8.5	345	3.0	25	1035	5.4	12.3	500	2.6	3320	7.0
Monks Corner WWTF	1.6	85.0	1141	1.5	128	1711	9.0	20.0	267	1.4	2931	6.2
Amoco	2.3	20.6	400	3.0	61.8	1200	6.3	0.0	0		1200	2.5
City of Hanahan	1.25	30.0	313	1.5	45	469	2.5	20.0	209	1.09	1,422	2.9
Dupont	1.3	45.7	504	3.0	137	1512	7.9	3.8	42	0.22	1703	3.5
Central BCW&SA	0.4	52.0	152	1.5	78	228	1.2	26.0	76	0.4	575	1.2
Texaco	0.2	30.0	48	1.5	45.0	71	0.4	20.0	32	0.2	216	0.1
Koch	0.1	30.0	20	1.5	45.0	30	0.2	20.0	14	0.1	92	0.1
SC Ports	0.1	30.0	14	1.5	45.0	21	0.1	20.0	9	0.0	64	0.0
C.R. Bard	0.2	14.1	23	1.5	21.1	34	0.2	0.0	0		34	0.0
RM Engineered	0.2	10.0	19	1.5	15.0	29	0.2	0.0	0		29	0.0
Detyens Shipyard	0.0	30.0	6	1.5	45.0	9	0.0	20.0	4	0.0	28	0.0
Daniel Island WWTP	0.3	5.0	10	1.5	7.5	16	0.1	1.0	2	0.0	25	0.0
SCE&G/Wms. Station	0.0	30.0	4	1.5	45.0	6	0.0	20.0	3	0.0	17	0.0
Girl Scout Council	0.0	30.0	3	1.5	45.0	5	0.0	20.0	2	0.0	14	0.0
Jeffries General Station	0.0	30.0	2	1.5	45.0	2	0.0	20.0	1	0.0	7	0.0

Amerada Hess, North	0.1	10.0	4	1.5	15.0	7	0.0	0.0	0		7	0.0
Cainhoy Elementary Packaging	0.1	5.0	3	1.5	7.5	5	0.0	0.0	0		5	0.0

APPENDIX A

MODELING ASSUMPTIONS FROM ATM REPORT:

The following discussion outlines the assumptions and methodology used by EPA in the calibration and verification of the 2D WQMAP water quality component of the wasteload allocation model. The hydrodynamic model calibration and verification are presented within a separate report entitled “Development of a Waste Load Allocation Model within the Charleston Harbor Estuary, Part I: Hydrodynamics and Mass Transport”.

The hydrodynamic and water quality models are solved over identical grids. This grid extends from approximately 3 miles offshore, through the harbor, and up each of the three tributaries, the Ashley, Cooper, and Wando Rivers. Additionally the grid extends up to the Pinopolas Dam, and down to the Back River reservoir through Durham Canal. Figure 2-1 presents the grid extents and resolution.

The model bathymetry was determined through a combination of existing NOAA data, measurements taken during the 1996 data collection, and data collected by USGS as part of the Charleston Harbor Project.

For the water quality simulations it was necessary to provide a total model spin up time of 30 days in order to reach equilibrium. For the 1996 simulations a combination of an idealized and a measured offshore forcing were used for the month of August to spin the model up. The last 10 days of the model spin up are real tides. For the 1993 simulations real measured tides for July were used to spin up the model.

In the hydrodynamic simulations, freshwater inflow rates were defined for 5 tributaries, the Pinopolas Dam, the headwaters of the Wando River, the headwaters of the Ashley River, the headwaters of the East Branch of the Cooper River, and the headwaters of Goose Creek. For Pinopolas Dam the flows were measured and input directly as measured flows. For the other rivers the flows were determined based upon simplified hydrologic evaluations with flow directly proportional to local rainfall and driven by rainfall events.

The water quality model component of WQMAP is based on the same boundary-fitted grid as the hydrodynamic model. It uses the hydrodynamic model output plus additional parameters to estimate the dynamic distribution of 8 state variables in the water column and underlying benthos. Figure 3-1 presents the principal kinetic interactions for the nutrient cycles and DO balance. The EPA WASP5 eutrophication model (Ambrose et al., 1994) forms the basis of the water quality model kinetics. The WASP5 kinetic rate equations have been incorporated into WQMAP to form a fully non-linear eutrophication, 2-dimensional, time-dependent, advection-diffusion model system in boundary-fitted, general curvilinear coordinates.

Within the WQMAP eutrophication model, 5 state variables can participate directly in the DO balance: phytoplankton carbon, ammonia, nitrate, carbonaceous BOD, and DO. Additionally, 3 state variables can affect the DO balance through the increasingly complex kinetic interactions: inorganic phosphorus, organic nitrogen, and organic phosphorus. The DO balance includes sources (reaeration and phytoplankton growth) and sinks (phytoplankton respiration, oxidation of carbonaceous material, and nitrification) in addition to the transport terms.

For the water quality model, concentrations along an open boundary, marsh storage, and river are calculated from a 1-D advection equation during outflow. During inflow, the concentration of each water quality parameter takes on a prescribed value. Table 4-1 presents the prescribed inflow concentration at the model boundaries (offshore, river, and marshes).

Section 2.0 described the offshore and river boundary conditions along with their flows and tidal fluctuations. In the model there are a total of 5 river boundaries, these are at the Pinopolas Dam, the East Branch of the Cooper River, Goose Creek, the Wando River, and the Ashley River. For the offshore and river boundary conditions, data from the closest STORET station were analyzed for each simulation period and mean values were specified for each of the 8 water quality state variables. These concentrations are constant and do not vary over time for the water quality simulations.

For the marsh storage areas, it was assumed that marshes are natural sinks for nitrate (high denitrification rates), while exporting ammonia, carbon and BOD. The concentration of ammonia and BOD coming out the marshes has an important role in establishing the background levels of those water quality constituents. The higher the relative influence of the background concentrations, the lower the net impact of the other oxygen demanding sources. Therefore, in order to have a conservative approach for the predictive ability of the model to evaluate the relative impact of the point source discharges, the boundary condition for the marshes were specified at the lowest calibration values possible that were in agreement with McKellar *et al.* (1996). A total of 23 marsh storage areas were prescribed throughout the system.

The sediment oxygen demand input to the model is a spatially varying file that remains constant throughout both the 1996 and 1993 simulations. Figure 4-1 presents a plot of the spatially varying SOD throughout the Charleston Harbor System. Appendix A presents the spatial varying file input into the model. The values range from 0.5 gm/m^2/day up to 1.6 gm/m^2/day. With the largest values generally found in the area of the upper Cooper River, and the lowest values in the area in the lower Harbor.

The point source load data were gathered from the various dischargers based upon data collected for the DMR reporting program. Where available, daily time series loads were used as input to the model. The loads prescribed for each discharger included (where applicable) Ultimate Carbonaceous Oxygen Demand (CBODU), Ammonia (NH3), and Dissolved Oxygen (DO). All loads were prescribed as a mass flux rate in gm/sec for the model. These were converted from the typical reporting units of lbs/day. For the 1996 simulations a total of 18 loads were prescribed as input for the model calibration. These are:

- North Charleston Water and Sewer Department (NCSD) WWTP
- Westvaco
- CPW Plum Island WWTP
- Lower Berkley County Water and Sewer Authority (LBCW&SA) WWTP
- Bayer
- Amoco

- Dupont
- Texaco
- South Carolina Ports
- RM Engineered
- Mt. Pleasant WWTP
- City of Hannahan
- Central Berkley County Water and Sewer Authority (CBCW&SA) WWTP
- Moncks Corner WWTP
- CR Bard
- Jeffries Station
- Summerville WWTP
- CPW Pierpoint WWTP

A 2-dimensional waste load allocation model has been developed for Charleston Harbor Estuary. Major conclusions of the study are summarized in the following:

1. A fine resolution numerical grid, which accurately represents the complex geometric and bathymetric features of the system was generated.
2. Circulation patterns produced by the hydrodynamic model revealed flow features that agree with the existing information, available from past modeling and the monitoring program conducted during August to October 1996.

Both the qualitative and quantitative comparisons between measured and simulated water quality parameters clearly indicate that the model is capturing most of the important physical and biogeochemical processes in the estuarine system.

TMDL MODEL INPUTS

TMDL Hydrodynamic Model Inputs:

MODEL INPUT / OUTPUT FILES	File Names	Location
Grid File	Grid39E	1993 Calibration CD

Time series location	Cooplong	
Scenario runhydro folder	Average	See table x
Output Currents folder	Average	
Elevation/Salinity/Temperature Seaward Open Boundary file	M2S2_93.HST	
River Boundary files	Pindam @ Constant value Temp = 28 C Salinity = 0 Flow = 85.24 m^3/day All others = 0.01 m^3/day flow (approximately zero)	

Hydrodynamic Model Parameters:	Values	Comments
RUN CONTROL		
Start Time	11/1/1993 0:00 AM	
End Time	1/1/1994 0:00 AM	
Run length (days)	61.0	
Interval for current timeseries	60.0	
Interval for current field output	60.	
Dated Current field output Start time:	11/1/1993 0:00 AM	
MODEL PARAMETERS		
Number of Z grids	1	
Time step (min)	10	
Ramp time period (min)	5760.	
Ramp for Wind (min)	0.0	
Turbulence start time (min)	0.0	
Residual start time (min)	5760.0	
Tubulence options	Richardson Number	
Bottom Boundary conditions	Slip condition, quadratic stress	
Processes	Friction	
Prognostic terms	None	
Advective Time step (min)	0.2	
Smoothing parameters East fraction West fraction	 1.0 1.0	
Bathymetry # of passes Center weighting	 10 0.550	
PHYSICAL PARAMETERS		
Friction coeff. At surface	0.0	
Vertical viscosity (m^2/sec)	0.0	
Vertical diffusivity (m^2/sec)	0.0	
Wind speed (m/s)	0	
Wind direction (degree)	0.0	
Advection options	Quickest	
False bottom	Yes	

Depth (m)	2.0	
Horizontal diffusivity (m^2/sec)	1.0	
Water density (kg/m^3)	1025.	
Air density (kg/m^3)	1.3	
Initial temperature (C) Constant Grid values	28.0	75% value of available data
Initial salinity (ppt) Constant Grid values	Use grid values	
Bottom Boundary conditions	Chezy	
Mannings N Constant Individual grid values	Grid cells vary	

Scenario	Altern#	
Hydro file	Average.bpc	
Time series locations	Cooplong	
Mass loads	Altern#	See table y
Open boundary seaward	NH3 = 0.05 NO3 = 0.1 PO4 = 0.04 PHY – not used BOD = 2.0 DO = saturation O-N = 0.5 O-P = 0.1 CM1 = tracer 1 CM2 = tracer 2	
Open River Boundary	NH3 = 0.05 NO3 = 0.1 PO4 = 0.03 PHY – not used BOD = 3.0 DO = saturation O-N = 0.49 O-P = 0.1 CM1 = tracer 1 CM2 = tracer 2	
Model control		
Scenario	Alternative #	
Description	BFWasp	
Start time	11/1/1993	
Run length	60 days	
Hydro data	Average.bpc	
Start time for conc output	12/1/1993	
Interval for conc output	60 minutes	
Interval for conc timeseries output	30 min	

Model parameters		
Kinetic tern test	Not tested	
Time step (min)	1.5	
Ramp period (min)	0	
Horizontal diffusivity (m^2/sec)	0.05	
Vertical diffusivity	0	
Water/sediment exchange (m^2/sec)	0.00015	
Conc report bypass	6	
Constitute bypass	PHY	
Nitrogen		
Nitrification rate (1/day)	0.035	
Other rates in order	1.04 2.0 0.15 1.08 0.1 0.2 0.04 1.08 0.65 0.001 1.08 0.4	
Phytoplankton	Not used	
Dissolved Oxygen		
Reaeration	Water_Wind Velocity	
Waterbody size	Large	
Reaeration rate	Calculated	
Temp coeff	1.047	
Endogenenous respiration	0	
Temp coeff	1.045	
Sediment O2 Demand (g/m^2-day)	1.5	Used grid file
Temp coeff	1.047	
Phosphorous	P:C = 0.025 Mineralization = 0.2 Temp Coeff = 1.08 Fraction Phy recycled = 0.2 Half Sat Constant = 1.0 Org P decay = 0.001 Temp Coeff = 1.08 Diss Frat of org P = 0.05	
CBOD	Deoxygen rate = 0.06/day Temp coeff = 1.03 Half sat = 0.5 O2/C ratio = 2.66 Fraction dis CBOD = 1 Organic settling = 0	

	CBOD sediment decomp rate= 0 Temp coeff = 1.08	
Nonreacting	All zero rates	
Time Functions		
Temperature	Constant 28 C	
Extinction	Constant 1	
Ammonium flux	Constant 1	
Phosphate flux	Constant 1	
Reaeration	Constant 1	Calculated
Herb. Zoo.	1	
Salinity	Constant 1	See report
Daily Solar radiation	File – Solar93B.dat	
% Day with light	1	Use data in above file
Wind Velocity	Constant 2.7	
Ambient Air	1.0	Grid defined
Ice	Open	
Spatial parameters		
Temperature	Constant 1	28 C
Extinction Coeff	File – sp_kz.dat	
Ammonium flux	Constant 0	none
Phosphate flux	Constant 0	none
Reaeration	Constant 1	Calculated
Zoo.	0	
Salinity	Constant 1	See report
SOD	File – sp_sod.dat	
% Day with light	1	Use data in solar file
Benthic layer thickness	Constant 0.2 meter	
Water Column Initial Conditions	NH3 = 0.05 NO3 = 0.02 PO4 = 0.2 PHY – not used CBOD = 2.5 DO = saturation O-N = 0.1 O-P = 0.1 CM1 = tracer 1 CM2 = tracer 2	
Benthic Column Initial Conditions	NH3 = 0.0 NO3 = 0.0 PO4 = 1.0 PHY – not used CBOD = 10. DO = 2.0 O-N = 1 O-P = 1 CM1 = tracer 1 CM2 = tracer 2	
Marsh Inputs	NH3 = 0.05 NO3 = 0.01	

	PO4 = 0.05 to 0.1 PHY – not used CBOD = 1.5 to 2.5 DO = 4.5 to 6.0 O-N = 0.1 to 0.3 O-P = 0.05 CM1 = tracer 1 CM2 = tracer 2	

APPENDIX B

POINT ONE JUSTIFICATION DOCUMENT

INTERNAL MEMORANDUM
SCDHEC, OCTOBER 2002

D H E C

PROMOTE PROTECT PROSPER

South Carolina Department of Health
and Environmental Control

MEMORANDUM

TO: File: Charleston Harbor System TMDL

FROM: Larry Turner, Manager
Water Quality Modeling Section

SUBJECT: Justification for Use of the 0.1 Rule for Determining Allowable Loadings of Oxygen Demanding Substances to the Charleston Harbor System

DATE: October 29, 2002

This memorandum is being written in response to comments, both written and oral, regarding the Department=s decision to apply the 0.1 Rule to develop a total maximum daily load for the Charleston Harbor system.

The State of South Carolina has adopted water quality standards (R.61-68) to protect water quality and water uses. Criteria, both numeric and narrative, have been adopted to ensure that uses are maintained. Narrative criteria describe a water quality goal that is to be attained while numeric criteria provide a numeric value that should not be exceeded or violated. For dissolved oxygen, a minimum value necessary to protect against both lethal and sub-lethal effects has been adopted and, for some waters, a daily average value has been established for additional protection.

R.61-68 has adopted certain critical flow conditions for application of numeric criteria for purposes of permit issuance, wasteload allocation, load allocation and mixing zone determinations. In tidal situations, the regulation requires that flows that approximate 7Q10 be used. The Department is required to issue wasteload allocations and permits that protect water quality for the conditions under which the standards are applicable, critical conditions of low flow and dilution and the conditions that could reasonably occur during such periods. Wasteload allocation analyses (models) are conducted based on these critical conditions.

R.61-68 acknowledges that certain naturally occurring conditions may cause a depression of dissolved oxygen in surface waters while existing and classified uses are still maintained. In these situations, Section D.4.a states the dissolved oxygen concentration shall not be cumulatively lowered more than 0.1 mg/l from point sources and other activities (0.1 Rule). Section D.4.b allows a depression greater than 0.1 mg/l only if it is demonstrated that resident aquatic species are not adversely affected (the A10% Rule@).

DHEC evaluates when the 0.1 Rule should apply on a case by case basis depending on the physical characteristics of the system, ambient water quality data and modeling. This approach was used successfully to apply the 0.1 Rule to develop a TMDL in the Waccamaw/ICWW system and to develop wasteload allocations for the Sampit River.

The Department looked at the three factors given above to determine if the 0.1 Rule should apply to the Charleston Harbor system as a whole. A qualitative evaluation of the physical characteristics of the system, data from DHEC=s ambient monitoring network and the USGS real time monitoring network established as part of the Charleston Harbor Project (CHP), and models developed as part of the CHP were used to determine if the 0.1 Rule should apply.

Qualitative Analysis of System Characteristics

A qualitative evaluation of the system was conducted. Based on experience with other tidal systems (Waccamaw River, Sampit River, Beaufort River) and information obtained by the SCDNR, it is known that tidal rivers with little freshwater inflow, such as the Ashley and Wando Rivers, experience depressed DO levels below the adopted numeric criteria. It is also known that in tidal rivers where freshwater inflow is relatively small compared to the tidal prism, DO can be depressed in the transition zone between tidal and non-tidal areas. Based on the characteristics of the system, it was determined that low dissolved oxygen concentrations were a natural phenomenon in the Charleston Harbor system.

Water Quality Data Analysis

Available water quality data for the system were reviewed. Ambient data collected by DHEC at several locations in the Cooper River showed only infrequent violations of the Aminimum of 4 mg/l@ standard. Data collected in the Ashley River showed sufficient violations (greater than 10%) of either the Aminimum of 4 mg/l@ or the Adaily average of 5 mg/l@ standard to be placed on the 303(d) list since at least 1996. The Ashley River was on the 1992 list; however, the parameter of concern was not specified.

As part of the Charleston Harbor Project, USGS operated a system of 15 continuous monitoring stations in the Ashley River (3), Wando River (4) and Cooper River (8) during the period October 1991 through September 1995. Not all stations were active for the entire period. Minimum, average and maximum dissolved oxygen levels were reported for those days when the stations were in operation and working properly. Table 1 summarizes compliance with applicable criteria for the months of June, July, August, September and October for each station with stations listed from upstream to downstream. These months were evaluated since stress due to naturally low dissolved oxygen concentrations are more likely to occur then. All of the stations have a requirement for a minimum of 4 mg/l DO while certain stations in the Wando and Upper Cooper Rivers have an additional requirement for a daily average of 5 mg/l. All daily values for each month for the period of record were evaluated. The number not meeting the standard was determined and the percentage of days violating for the month was calculated.

Monitoring results show that all stations in the Wando River violated both the minimum of 4 and daily average of 5 mg/L criteria greater than 25% of the days for which data were available for the months of July, August and September. In addition, two stations violated both criteria greater than 25% of the time in June and one station in October. All stations violated both criteria during August more than 49% of the time. For the Cooper River, results were more varied with one station (Cooper River at Customs House) showing no violations while one (Cooper River at Army Depot) violated the minimum requirement of 4 mg/L more than 75% of the days in June, July, August and September. With the exception of the Cooper River at the Customs House, all stations in the Ashley, Cooper and Wando Rivers and Charleston Harbor experienced violations of the dissolved oxygen standard at some time during the summers of 1992-1995. Violations were especially prevalent during the month of August with violations ranging from infrequent to almost continuous depending on the station.

Model Evaluation

The modeling effort for the Charleston Harbor system has been ongoing since the early 1990's. The initial effort, part of the Charleston Harbor Project (CHP), was to develop separate models for the Ashley and Cooper Rivers and link them to a model for the harbor. Due to linkage problems, the harbor model was dropped. Additionally, the decision was made for the US Geological Survey to use the BRANCH/BLTM modeling platform for the rivers rather than the WASP platform. The BRANCH/BLTM model for the Cooper was extended downstream to include the Wando River. The BRANCH/BLTM model was developed to the point where it could be used to evaluate load vs. no load situations. The model predicted that under critical conditions with the dischargers removed, the system would not meet the water quality criteria for dissolved oxygen.

While the BRANCH/BLTM model was under development, the Charleston Commissioners of Public Works proposed development of another model using the WQMAP system. The WQMAP model was to include the Charleston Harbor/Cooper River/Ashley River system. The CPW had plans for a new discharge to be located on Daniel Island near the lower boundary of the BRANCH/BLTM model. CPW officials proposed the new model because they feared the BRANCH/BLTM model would not be able to evaluate the new discharge. A workgroup including participants from DHEC, USGS, USC, EPA, ATM (developers of the WQMAP model) and the SC Coastal Conservation League concluded that the BRANCH model, which had relatively short run times, could be used as a screening tool to narrow options to be evaluated with the WQMAP model. ATM agreed with the conclusion to evaluate the system using the 0.1 Rule (see ATM APresentation to SCDHEC: Suggested Modifications to Surface Water Quality Classifications and Standards,@ December 12, 1996, portions attached). Not only did ATM agree with the application of the 0.1 Rule, they provided DHEC with a post-processor to allow extraction of data at selected points in the model to allow evaluation of model results based on the 0.1 Rule.

Conclusions

The system as a whole does not consistently meet numeric water quality criteria for dissolved oxygen for significant periods of time during the summer months. The frequency and aerial extent of violations during the summer months would indicate the violations could not be solely associated with existing point source discharges. The system is poorly flushed with modeling indicating DO criteria would not be met during critical summer months even without point source inputs. Based on this information, it is appropriate to use the 0.1 Rule for evaluation of discharges to the entire system.

Summary of Findings from Analysis of Historic Data

- UBOD loads to the Cooper River have ranged from 50 to 100 percent of the presently proposed permit limits over the past 20 years.
- Dissolved oxygen conditions on the Cooper River on the average are equal to or better than the Ashley and Wando Rivers.
- BOD5 levels on the Cooper River (below the tee) are on the average lower than the levels in the Wando and Ashley Rivers.
- Slight increases in Ammonia concentrations can be seen in the immediate vicinity of the NCSD discharge.
- Areas of peak Nitrate/Nitrite concentrations on the Cooper River do not coincide with the areas of peak Ammonia concentrations.
- Total Nitrogen levels and BOD5 levels show similar spatial characteristics and do not appear to reflect impacts from the discharges.
- The most significant impact upon dissolved oxygen levels (other than water temperature) appears to be non-point source loadings associated with rain events.
- These non-point source load events create conditions where daily average dissolved oxygen levels throughout much of the Lower Cooper River, the Wando River, and
- Therefore under the existing SCDHEC rules and regulations, the maximum allowable anthropogenic dissolved oxygen deficit allowed within these areas is 0.1 mg/L.

ATM

Table 1 Frequency of Violation of Applicable Dissolved Oxygen Criteria

Ashley River

% violation of minimum DO 4

Station	**June**	**July**	**August**	**Sept**	**Oct**
02172081 Ashley at Cooke Crossroads	64.5	62.3	68.3	37.9	16.7
021720869 Ashley near N Charleston	38.3	93.3	79.7	79.7	3.6
02172090 Ashley at Charleston	11.8	57.6	53.3	40.7	0.0

% violation of daily avg DO 5

Station					
02172081 Ashley at Cooke Crossroads	51.6	81.8	88.9	83.9	38.5
021720869 Ashley near N Charleston	NA	NA	NA	NA	NA
02172090 Ashley at Charleston	3.9	34.8	40.0	23.3	1.4

Wando River

% violation of minimum DO 4

Station	**June**	**July**	**August**	**Sept**	**Oct**
021720695 Guerin Creek	80	100	100	82.6	6.3
021720694 Wando at Ward Bridge	46.2	86.8	88.2	64.9	29.2
021720696 Wando at Cainhoy	23.4	73.8	59.6	51.8	0
021720698 Wando at 526	18.1	31.9	58.6	44.9	3.6

% violation of daily avg DO 5

Station					
021720695 Guerin Creek	74.5	100.0	100.0	83.7	11.4
021720694 Wando at Ward Bridge	91.0	95.6	91.8	85.1	39.3
021720696 Wando at Cainhoy	20.3	45.9	55.1	64.7	0.0
021720698 Wando at 526	9.7	26.1	49.4	37.7	3.6

Cooper River

% violation of minimum DO 4

Station	**June**	**July**	**August**	**Sept**	**Oct**
021720011 Tailrace Canal below Lake Moultrie	49.4	74.2	27.2	17.0	0.0
02172040 Back River at Dupont Intake	18.3	25.0	29.0	30.0	0.0
02172037 East Branch Cooper River	2.2	46.6	38.2	37.4	15.2
02172050 Cooper River below the 'T'	0.0	0.0	9.1	2.0	0.0
02172053 Cooper River at Mobay	0.0	10.0	22.0	0.0	0.0
021720675 Cooper River at Army Depot (Goose Cr)	79.5	92.5	88.4	77.0	3.1
021720710 Cooper River at Customs House	0.0	0.0	0.0	0.0	0.0
02172100 Charleston Harbor at Fort Sumter	0.0	12.1	24.3	4.3	0.0

% violation of daily avg DO 5

Station					
021720011 Tailrace Canal below Lake Moultrie	36.1	64.4	19.1	15.9	0.0
02172040 Back River at Dupont Intake	15.0	27.5	35.5	37.5	0.0
02172037 East Branch Cooper River	4.4	29.5	25.5	20.6	3.3
02172050 Cooper River below the 'T'	NA	NA	NA	NA	NA
02172053 Cooper River at Mobay	NA	NA	NA	NA	NA
021720675 Cooper River at Army Depot (Goose Cr)	NA	NA	NA	NA	NA
021720710 Cooper River at Customs House	NA	NA	NA	NA	NA
02172100 Charleston Harbor at Fort Sumter	NA	NA	NA	NA	NA

Table 2. Range of Observed Dissolved Oxygen Values During 1992-1995*

Waterbody	Station Number	Station Location	June		July		August		September		October	
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Ashley River	02172081	Ashley River at Cooke Crossroads	1.7	11.7	0.9	10.7	1.9	9.4	2.9	7.6	0.2	8.1
	021720869	Ashley River near N. Charleston	3.0	7.9	1.5	8.4	2.3	7.7	2.3	6.6	3.3	7.5
	02172090	Ashley River at Charleston	1.2	9.7	0.0	8.8	0.1	9.2	2.1	7.6	3.2	9.9
Wando River	021720695	Guerin Creek	2.0	7.6	1.4	6.9	1.0	6.2	1.2	6.9	2.5	8.3
	021720694	Wando River at Ward Bridge	2.4	6.6	2.2	7.4	1.9	7.2	1.6	7.6	2.7	8.2
	021720696	Wando River at Cainhoy	3.0	8.1	2.6	8.7	2.3	8.4	2.4	6.8	4.0	8.1
	021720698	Wando River at I-526	3.2	9.3	3.2	9.5	2.8	9.6	2.3	8.7	3.3	8.2**
Cooper River	021720011	Tailrace Canal below Lake Moultrie	0.2	8.0	0.6	7.6	1.2	8.8	1.7	10.1	4.4	9.8
	02172040	Back River at Dupont Intake	2.7	9.0	2.2	7.3	2.6	6.4	2.5	7.6	no data	no data
	02172037	East Branch Cooper River	3.8	8.1	2.5	9.5	2.0	9.0	1.8	9.9	0.0	10.9
	02172050	Cooper River below the "Tee"	4.3	7.7	4.2	6.9	3.4	7.4	3.7	7.3	5.1	9.0
	02172053	Cooper River at Mobay	4.0	7.3	3.2	6.8	3.2	7.1	4.1	6.6	5.8	7.9
	021720675	Cooper River at Army Depot (Goose Creek)	2.6	7.5	1.5	8.1	1.6	7.8	2.2	8.1	3.2	8.8
	021720710	Cooper River at Customs House	2.3	8.7**	4.0	8.0**	4.1	9.1	4.3	9.1	4.7	8.5
	02172100	Charleston Harbor at Ft Sumter	4.4	10.3	3.2	10.6	2.9	10.1	3.5	10.4	4.0	9.2**

*Charleston Harbor Project USGS electronic dataset used for this analysis as provided to SCDHEC on 3/2/01.
**Spurrious value from electronic dataset replaced with USGS published value.

APPENDIX C

RESPONSIVENESS SUMMARY
TO
PUBLIC COMMENTS ON INITIAL DRAFT COOPER RIVER TMDL

SUMMARY OF PUBLIC COMMENTS AND DEPARTMENTAL RESPONSES FOR DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) FOR THE COOPER RIVER (Based on December 2000 Draft TMDL Notice)

Note: The Department received a significant number of comments from a wide variety of commenters regarding the draft TMDL and included governmental entities, private industries, and individual members of the public. The Department has organized this responsiveness summary so that the comments will appear grouped by the issues to which they apply. There is no inference of importance or meaning given to the order in which the comments are addressed. The list of those commenting on the draft TMDL is attached.

Issue: Several commenters stated that the Department had not substantiated the water quality target on which the draft TMDL was based saying that the application of the 0.1 Rule contained in Section D. of S.C. Regulation 61-68, *Water Classifications and Standards* (R.61-68) was inappropriate. Their comments contained several specific points, each addressed separately below:

1. Comment: The commenters state that the Department must define how compliance with the dissolved oxygen (DO) standard will be measured in the tidally influenced Cooper River and then prove that the defined standard has not been achieved and that the Department had done neither. The commenters also state that the Department=s own Section 305(b) and 303(d) guidance stated that we used the 90th percentile for compliance purposes and that their review of the data indicated that the 90th percentile was in compliance, so therefore, the Cooper River did not have a problem with DO.

Response: The Department has defined compliance with the DO standard for the Cooper River which has two different classifications throughout the system. Both of these classes require at least a minimum of 4.0 mg/l DO (See R.61-68.G.). The Department=s interpretation of the regulatory minimum requirement language of Anot less than 4 mg/l@ is that any recorded value of a DO reading which is below the 4.0 mg/l is a violation of the DO standard which is the duly-promulgated standard effective on the Cooper River. This same interpretation has been applied since the DO standards were first promulgated in 1950.

As to how the Department determines compliance with the effective water quality standard, the Department has not and does not consider a single violation of the 4.0 mg/l DO standard as its rationale for making the determination that the Cooper River does not attain the Anot less than 4.0 mg/l@ standard whether it be applied as an instantaneous measurement, a one-hour average measurement, or several measurements collected over a day. As proof of the substantial nonattainment of the DO standard, the Department has provided to the specific commenters (and is presented in Appendix B of the revised draft TMDL), ample data that verifies that the DO standard of a minimum of 4.0 mg/l is not being met for sustained periods of time during the year. This is shown consistently at various locations throughout the Cooper River waterway.

As to the commenters= assertion that the 90th percentile should be used for determining compliance with water quality standards for the assessments for Section 305(b) and Section 303(d), the Department responds by stating that we follow EPA guidelines on how to assess our waters for attainment of uses. The guidelines do not recommend using the 90th percentile to determine compliance. What the 305(b) guidelines recommend is that states review all applicable water quality data collected in its waters during a specified time period. Of that data, EPA recommends that when more than 10% of the values fail to meet the applicable water quality standard, then the waterbody is assessed as not fully supporting the use for which that criterion was established. That is not the same as the 90th percentile of samples collected. The 90th percentile refers to arranging all values taken in order of magnitude, and then noting where the 90% mark of those values occurs.

2. Comment: The commenters state that the Department has never defined the flow conditions to be used as the basis for defining how compliance with the DO standard will be measured and cite a portion of R.61-68.C.

Response: The duly-promulgated effective DO standard for the Cooper River waterway states that a minimum of 4.0 mg/l DO will be the measure of DO attainment. This means that if you take an instream measurement of the Cooper River where this minimum value applies and it is below 4.0 mg/l, then that measurement does not meet the applicable water quality standard and is a violation. The commenters have misinterpreted the section of R.61-68 which they cite. This section was written to deal with the application of aquatic life numeric criteria when determining the design conditions for permitted activities.

3. Comment: The commenters state that because the Cooper River was not on the Department=s 2000 Section 303(d) List of Impaired Waters, the Department should not have applied the 0.1 Rule contained in R.61-68.D.4. The commenters continue that the Department has made no attempt to prove that the DO standard would not be attained due to natural conditions and therefore, again, the Department should not have applied the 0.1 Rule.

Response: Consistent with Federal statutory and regulatory requirements under Section 303(d) of the Federal Clean Water Act and 40 CFR 130.7, the Department evaluates water quality data and information and makes its determination of attainment of applicable water quality standards and prepares a biennial list of impaired waters known as the Section 303(d) List. R.61-68.C.9. states, ABecause of natural conditions some surface or ground waters may have characteristics outside the standards established by this regulation. Such natural conditions do not constitute a violation of the water quality standards; however, degradation of existing water quality is prohibited unless consistent with Section D.4. of this regulation.@ This applicable water quality standard provision allows the Department to make the determination of whether there are natural influences that we believe have substantially contributed to excursions of the numeric criteria for DO in certain site-specific situations. The Department, along with other Federal and State agencies, private consultants, scientists and, including the United States Environmental Protection Agency, agrees that one of the natural characteristic phenomena of water quality in tidally-influenced areas of South Carolina is low DO levels, especially during high temperatures. Data collected in least-impacted areas have also confirmed the observations. Using the above-cited provision of the water quality standards, the Department made the decision that the Cooper River waterway was not impaired, but rather, we consider the system to have limited assimilative capacity with regard to DO. For this reason, it does not appear on the Section 303(d) List. Since the Department has made this decision, we must apply the 0.1 Rule when determining allowable pollutant loadings. As to the commenters= statement that they believe that the Department cannot support its claim that natural conditions are responsible for the low DO situations in the Cooper River, the Department has presented data showing that portions of the Charleston Harbor System do not meet the appropriate dissolved oxygen standard for significant periods of time and have provided this data in Appendix B of the revised draft TMDL.

Issue: The commenters state that the Department violated State law in developing the draft TMDL.

4. Comment: The commenters state that the Department=s establishment of the Cooper River draft TMDL violated the South Carolina Pollution Control Act (PCA) by saying that they believe that the draft TMDL should be promulgated as a regulation and cite Section 48-1-30 which states: AThe Department shall promulgate regulations to implement this chapter to govern the procedure of the Department with respect to meetings, hearings, filing of reports, the issuance of permits and all other matters relating to procedures.@ They also continue that the Department has violated the South Carolina Administrative Procedures Act (APA) and cite Section 1-23-10.

Response: The Department has not violated the PCA or the APA, since a draft TMDL, by its very site-specific nature, is not a regulation. Section 1-23-10 of the APA defines a regulation as follows: ARegulation means each agency statement of general public applicability that implements or prescribes law or policy or practice requirements of any agency. Policy or guidance issued by an agency other than in a regulation does not have the force or effect of law.@ As the commenters also note, the courts have held that a regulation establishes a Abinding norm@ which would not allow the Department to have discretion on whether to follow general guidance or policy in an individual case. Essentially this means that if we consider the Cooper River draft TMDL a regulation, and therefore a binding norm, the draft TMDL would have the ability to be applied by the Department anywhere in the State. The Cooper River draft TMDL was developed using models that were finely tuned and developed for the Cooper River waterway. These models have inputs that are specific to the Cooper River waterway. Data and information that was gathered on the Cooper River waterway were used in both the models and in the development of the draft TMDL and that is the only way that a true TMDL can be developed. The commenters stated, TMDLs must be site-specific since they are essentially the maximum loading that a waterbody can assimilate without causing water quality standards violations. The TMDL cannot be developed if it does not include site-specific conditions. There is no way that the Department can use the Cooper River draft TMDL for any other waterbody in the State. Therefore, the Cooper River draft TMDL cannot be a Abinding norm@ since none of it is general policy or guidance, but is developed expressly, singularly, and individually for the Cooper River waterway.

Issue: The Department=s administrative record supporting the Cooper River draft TMDL is legally deficient.

5. Comment: The commenters state that under the APA, the Cooper River draft TMDL should have gone through the administrative process for regulation development which included such items as a Preliminary Assessment Report (PAR) and sent to the South Carolina State Legislature for their approval as a regulation.

Response: While the APA does require that regulations must include a PAR and some be submitted to the General Assembly for approval, the Cooper River draft TMDL is not a regulation and these requirements do not apply.

6. Comment: The Department has failed to provide interested persons with access to information, including technical data and calculations, relevant to the proposed Cooper River draft TMDL.

Response: Certain technical information and model runs upon which the initial draft TMDL was based were not available for review by the respondents and their consultants. The Department has worked with EPA Region 4 and Applied Technology and Management (ATM), model developer and consultant for the Cooper River Water Users Association and other entities impacted by the draft TMDL, to ensure the revised draft TMDL is properly documented. The base Water Quality Mapping and Assessment Package (WQMAP) model developed by ATM along with the no load and load runs used to verify the final loadings as determined using the EPA developed TMDL calculator are available on compact disk as part of the revised draft TMDL. These have been made available to ATM and are available to others upon request. The Department has also worked to supply information supporting model inputs and technical decisions such as use of the 0.1 Rule. This information has been incorporated into the revised draft TMDL.

Issue: The commenters state that the Department deprived interested parties of their public participation rights by skipping the Section 303(d) listing process.

7. Comment: The commenters state that the Department was required to list the Cooper River as an impaired waterbody on its Section 303(d) List of Impaired Waters before developing a TMDL as required by Section 303(d)(1)(C) of the CWA.

Response: The idea that only waters that are listed on the Section 303(d) List of Impaired Waters may have TMDLs developed for them is incorrect. TMDLs are tools to be used by States to best maintain and protect their water uses. States may develop TMDLs for any of its waters when it believes that assimilative capacity may be close to or at a level that any further degradation may result in the waterbody no longer supporting its classified and existing uses. This is the case for the Cooper River waterway. After much discussion among all interested parties over the past decade, it became clear to the Department that a TMDL would ultimately solve the many disputed issues among all stakeholders and provide the best solution for both the regulated community as well as the environment. Further, the Department publicly noticed the Cooper River draft TMDL. These comments and this responsiveness summary are part of that public participation process.

8. Comment: Several commenters state the Department=s findings and conclusions in the Cooper River draft TMDL are clearly erroneous. These commenters contend the Department developed the draft TMDL using scientifically deficient modeling procedures and assumptions and, therefore, the conclusions presented are erroneous under South Carolina Law.

Response: The Department had several concerns with the initial model used in the development of the Cooper River draft TMDL and since the initial public notice there have been several refinements. EPA Region 4, in their report entitled *Charleston Harbor TMDL Model Review , Ashley Cooper River System, Jim Greenfield, EPA Region 4: Final Review Package April 2002*, (EPA report included as Appendix A) concluded Athe 2-D WQMAP model used to develop the proposed TMDL for oxygen demanding wastes for the Charleston Harbor System is a technically defensible model and is acceptable for calculating the wasteload allocations for point sources discharging to the Charleston Harbor System.@ Based on the Department=s and EPA=s reviews, these revised findings and conclusions are not erroneous.

9. Comment: Several commenters state that the Department used an inappropriate margin of safety (MOS). These commenters contend that the Department used an Aimplied margin of safety@ based on overly conservative modeling assumptions and then incorrectly applied an additional 10% MOS. This contention is based on the statement in the draft TMDL that the ACOG=s 208 plan specifies 10% of the available assimilative capacity will be held in reserve, for stream sections that are identified to be effluent limited.@

Response: The commenters are correct in that an MOS was based on conservative modeling assumptions. Based on the State/EPA wasteload allocation agreement and EPA=s recommendations on use of critical conditions, the critical conditions for flow, tidal conditions, background pollutant loading and discharger loadings were appropriate and consistent with accepted modeling conventions. EPA Region 4 has confirmed this in their acceptance of the critical conditions for use in the additional modeling conducted as a result of comments submitted by dischargers and others on the draft TMDL. The contention that the Department has included an additional 10% MOS in the draft TMDL is incorrect. The statement concerning the Council of Governments= (COG) Section 208 plan was included in the draft TMDL to reflect our understanding at the time that the COG intended to hold 10% of the available load in reserve, not as a MOS but for future growth. That provision is not in the latest Berkeley-Charleston-Dorchester COG Section 208 plan nor do the COG proposed allocations provided to the Department in September of 2002 specifically allocate any load to future growth. Reference to a 10% reserve is not included in the revised draft TMDL.

10. Comment: One commenter urges the use of an explicit MOS and contended that the conservative assumption of modeling permitted sources at full permit limits should not be considered part of the margin of safety.

Response: Current TMDL requirements allow either an implied MOS or an explicit MOS to address the uncertainty present to some degree in all predictive models. The commenter is correct in that the draft TMDL model incorporates the implicit MOS approach by the selection of conservative modeling parameters and critical conditions. Based on our understanding of the State/EPA wasteload allocation agreement and EPA=s recommendations on use of critical conditions, the critical conditions for flow, tidal conditions, background pollutant loading, and discharger loadings are appropriate and consistent with accepted modeling conventions. It is appropriate to consider use of full permitted loads as a component of the MOS since it is assumed that all dischargers will be discharging their full load at the same time and under critical conditions. Based on the

Department=s experience, this is a conservative assumption that can appropriately be considered as part of the MOS. EPA Region 4 addressed the question of an appropriate MOS in their report on the draft TMDL modeling effort. They state; AOne item the sensitivity report did point out is that there is considerable uncertainty in the 2-D Charleston Harbor Model. Based on the TMDL regulations, the TMDL must contain a MOS to address this uncertainty. Options for addressing the model uncertainty are to either assign an explicit MOS based on the sensitivity analysis or incorporate an implicit MOS by using reasonably conservative modeling parameters and critical conditions. The EPA and DHEC draft TMDL model incorporates the implicit MOS approach by the selection of conservative modeling parameters and critical conditions. In my opinion, the use of other modeling parameters and critical conditions as indicated in the sensitivity report, would have required the use of an explicit MOS because of the demonstrated model uncertainty, and the resulting TMDL would have been similar.@

11. Comment: Several commenters state that the Department was unable to provide the WQMAP model inputs and output file used to develop the draft TMDL report.

Response: While the Department was able to provide representative model runs to document development of the draft TMDL, we were unable to provide the exact runs used to develop the draft TMDL. In response to this and other comments, EPA Region 4 personnel conducted a thorough review of the draft TMDL modeling effort. EPA worked with the Department and ATM to ensure all were using the same base model. EPA has documented its review effort in a report. A copy of the EPA report is included in the revised draft TMDL. In addition, as part of the revised draft, ATM and the COG have been provided the appropriate model input files.

12. Comment: Several commenters state that the Department could not provide any documentation of conformance to EPA recommendations. This comment refers to an EPA recommendation for a Asubjective comparison@ of predicted no load dissolved oxygen concentrations with existing dissolved oxygen data.

Response: While the recommended Asubjective comparison@ was completed by the Department, formal documentation of the process was not available for review as part of the initial draft TMDL. For the revised draft TMDL, the Ano load@ model run used in the TMDL analysis conducted by EPA Region 4 is included as part of the CD provided. The EPA report concluded Athe 2-D WQMAP model used to develop the proposed draft TMDL for oxygen demanding wastes for the Charleston Harbor System is a technically defensible model and is acceptable for calculating the wasteload allocations for point sources discharging to the Charleston Harbor System...@ and, as such, has found the model is appropriately applied for conditions within the range of model calibration data.

13. Comment: Several commenters state that the Department modeling staff used incorrect hydrodynamic inputs for development of WQMAP model runs. These comments specifically referred to the bottom friction values used in the model.

Response: In response to these questions and other comments, EPA Region 4 was requested to conduct a complete review of the model. All inputs for the revised draft were evaluated and modified as needed. Bottom friction is appropriately handled in the revised model.

14. Comment: Several commenters state that the Department did not include saltwater marsh exchange in the WQMAP model runs.

Response: Marsh loadings are appropriately handled in the revised model.

15. Comment: Several commenters contend that it could not be determined that algal production was properly considered in the draft TMDL model runs.

Response: Algal processes are appropriately handled in the revised model.

16. Comment: Several commenters state that the Department incorrectly set critical conditions parameters in WQMAP model runs provided. These comments specifically referred to wind speed inputs.

Response: Wind speed is appropriately handled in the revised model and is set to the value recommended by the model developer.

17. Comment: Several commenters state that the Department used an inappropriate nitrification rate coefficient when developing the Branch Lagrangian Transport Model (BLTM) and WQMAP models.

Response: The nitrification rates used in both the BLTM and the WQMAP models were based on conditions in the river when the models were developed by the United States Geological Survey (USGS) as part of the Charleston Harbor Project and by ATM, consultants for the Cooper River Water Users Association. The rate used in the WQMAP model for the initial draft TMDL was the calibrated value provided by ATM. Subsequent to collection of the calibration data set, a major discharge of ammonia to the system was eliminated. Though the model was calibrated to the original data set, ATM recommended use of a lower nitrification rate due to the decrease in ammonia discharged to the system and proposed a study to document a lower instream decay rate. In consultation with EPA Region 4, the Department concluded the proposed study plan was inadequate and recommended more intensive sampling. A revised study plan was not provided and the instream study was not conducted prior to issuance of the draft TMDL. The Department chose to use the calibrated value provided by the consultant rather than use an estimated value. After issuance of the draft TMDL, work was done by ATM to document the instream decay value. The resulting value, 0.035/day, was provided, along with appropriate documentation, to EPA and the Department for use in the revised model. This value was used in developing the revised draft TMDL.

18. Comment: Several commenters state that the Department could not provide documentation to determine model sensitivity or a proper uncertainty analysis.

Response: Subsequent to TMDL comments being made, ATM submitted a report to EPA Region 4 and the Department entitled: *ATM Review of Model Inputs and Sensitivity Analysis for TMDL Simulations, Charleston Harbor System*. In his letter to Alton Boozer of May 2, 2002, Jim Greenfield of EPA Region 4 states the following; AOne item the sensitivity report did point out is that there is considerable uncertainty in the 2-D Charleston Harbor Model. Based on the TMDL regulations, the TMDL must contain a MOS to address this uncertainty. Options for addressing the model uncertainty are to either assign an explicit MOS based on the sensitivity analysis or incorporate an implicit MOS by using reasonably conservative modeling parameters and critical conditions. The EPA and DHEC draft TMDL model incorporates the implicit MOS approach by the selection of conservative modeling parameters and critical conditions. In my opinion, the use of other modeling parameters and critical conditions as indicated in the sensitivity report, would have required the use of an explicit MOS because of the demonstrated model uncertainty, and the resulting TMDL would have been similar.@ Mr. Greenfield further stated that if provided a well-calibrated, 3-D model with limited uncertainty, EPA and the Department could revisit the TMDL modeling. He concluded by saying AUntil this happens, I still recommend using the existing model for wasteload allocation purposes.@ The proposed draft TMDL includes provisions for development of a 3-D model which will address model sensitivity.

19. Comment: Several commenters contend WQMAP was used to predict only changes in dissolved oxygen levels from dischargers. These commenters contend that the WQMAP model is capable of predicting actual background dissolved oxygen levels under various loading conditions and that the Department chose not to require development of the model in the proper manner. Further, the commenters state that the Amodel developed by DHEC@ was unable to accurately predict dissolved oxygen changes as small as 0.1 mg/l. They also contend

Athe Waste Load Allocation Model for the Charleston Harbor System developed by DHEC cannot be used to accurately predict DO changes of 0.5 mg/l or less.

Response: The Department does not dispute that the full capabilities of the WQMAP model were not utilized in the Charleston Harbor application. However, all modeling efforts are limited to some degree by time constraints, funding limitations and manpower resources. The model developed by ATM for the Cooper River Water Users Association is no exception. A great deal of effort was expended by the Department, ATM, EPA, USGS and others to ensure the model developed by ATM was appropriate for the stated purpose given the time, manpower and financial constraints both on the Department and on the model developer. The commenter used terms such as Athe DHEC configuration of the model,@ Athe model as configured by DHEC,@ and, Athe model as it was applied by DHEC@ to refer to the modeling effort. The WQMAP model was developed, parameterized and configured by an outside consultant, ATM, and not the Department. This consultant was fully aware of the way in which the model was to be applied. The consultant worked very closely with the Department, EPA, USGS, and others to ensure the model was an appropriate tool for the assigned task. The model developer had a complete understanding of how the model would be applied and presented it to the Department with assurance that, while conservative, it was an appropriate tool to evaluate no-load vs. load scenarios at the 0.1 mg/l level. After thorough review and updating as needed, EPA Region 4 has concluded the model Ais a technically defensible model and is acceptable for calculating the wasteload allocations for point sources discharging to the Charleston Harbor System at non-wet weather critical conditions.@

20. Comment: Several commenters question the Department=s use of conservative assumptions. They contend the use of a two-dimensional, rather than a three-dimensional model, combined with critical background conditions results in a model that is overly conservative.

Response: EPA has evaluated the Charleston Harbor Project (CHP) TMDL modeling effort and reviewed all inputs including critical conditions. With the exception of adjustment of the nitrification rate, the inclusion of appropriate bottom friction values and assurance that the wind kinetics and marsh loadings were included in the critical condition model, the critical conditions selected by EPA for the predictive modeling are the same as those applied in the Department=s model. While use of the 2-D model is considered an additional conservative factor, EPA has concluded that the model is a technically defensible model acceptable for calculating wasteload allocations for point source dischargers to the Charleston Harbor System. The conservativeness of the 2-D model is to be addressed in Phase 2 of the TMDL in which a 3-D model of the system is to be developed.

21. Comment: One commenter questions the rationale for the determination of specific stream segments and questions the segmentation which, they said, results in no opportunity for trading or partnering to improve water quality.

Response: During their review of the initial draft TMDL, EPA seriously considered the segmentation question. In consultation with the Department and ATM, a revised segmentation was agreed upon which takes into account the physical and chemical characteristics of the waterbodies. This was made possible by development by ATM of more powerful post processors to evaluate the data. This and other aspects of the EPA review resulted in reasonably defined critical segments and development of a ATMDL calculator@ that allowed for easy evaluation of alternative loadings and the consideration of trading options requested by the commenter.

22. Comment: One commenter states that the Department must develop specific criteria, through rule-making, to specify when the 0.1 Rule would be utilized.

Response: Section D.4. of R.61-68 clearly specifies when the Department uses the 0.1 Rule.

23. Comment: One commenter suggests that the draft TMDL allocate the loading that might become available under the 10% rule.

Response: R.61-68 provides two options for waterbodies that do not meet standards for dissolved oxygen under certain circumstances. The first is a 0.1 mg/l depression below Abackground@ conditions. The second allows up to a 10% depression below natural background provided it is shown that the most sensitive species present in the system is not adversely impacted by the lower dissolved oxygen levels. Though a complex analysis is required to determine the allowable 0.1 mg/l deficit below background, the 0.1 Rule can be applied to any situation where the D.O. standard is judged to not be met due to natural conditions. The 10% rule involves a great deal more site specific evaluation in terms of determining resident species and, if not available, developing information as to the absolute dissolved oxygen requirements of the most sensitive species in the system. Modeling requirements may be much more stringent since the model will have to accurately predict dissolved oxygen levels on a much smaller time scale than a model developed to look at an average deficit over a 24 hour period. Unless the developers of the proposed 3-D model, to be developed in phase 2 of the TMDL effort, propose to apply this provision of the standard and comply with all the requirements of 48-1-83 et seq. (1976, as amended), Code of Laws of South Carolina 1976, Pollution Control Act and the AMethodology for Determining a Permitting Dissolved Oxygen Deficit Allowance for Waters Not Meeting Numeric Standards Due to Natural Conditions,@ these alternate loadings can not be determined for inclusion in the TMDL.

24. Comment: One commenter recommends the Department Aensure that any reductions that may be part of any final TMDL for the Cooper River are expressed to allow seasonal (if not monthly or flow based) application in ensuing NPDES permits.@

Response: The Department will consider use of seasonal limits consistent with water quality standards and NPDES permitting regulations. R.61-68 requires use of an annual 7Q10 for determining wasteload allocations, with the only exceptions defined in Section C.4.c.

25. Comment: One commenter recommends the draft TMDL be written to be flexible thus allowing refinements without having to redo the entire process.

Response: The Department recognizes that TMDLs can be modified or changed based on new information or evaluations that provide a better estimate of the water=s assimilative capacity. The currently proposed phased approach which allows development of a more precise 3-D model while making reasonable progress toward reducing permitted loadings to the system reflects the flexibility requested by the commenter.

26. Comment: One commenter provides information on dissolved oxygen concentrations in the Charleston Harbor System as supportive information and recommends implementation of the draft TMDL to reduce the discharge of oxygen demanding substances to the system.

Response: The data and information have been included in the TMDL record.

27. Comment: One commenter states that a completed TMDL must account for a load allocation for non-point sources (NPS) as well as the wasteload allocation for point sources and the MOS and that the treatment of the load allocation must be made explicit.

Response: While the initial phase of the TMDL will address only point source wasteload allocations, the 3-D modeling to be conducted in phase 2 of the TMDL will also address non-point sources. During the phase 1 period, the Department will continue to address NPS pollution through other programs including the NPDES and MS4 permitting programs, the 401 Certification program, the state Stormwater Management and Sediment Reduction Act and other programs to control non-point sources of pollution.

28. Comment: One commenter states that it was unclear what flow had been used as the critical low flow boundary input for the discharge at the Pinopolis Dam and suggested an inappropriately high flow had been used.

Response: The weekly average 4,500 cfs flow requirement is a goal, however, lower flows are experienced. Based on the flow data available at the time the draft TMDL was issued, the lowest weekly average flow experienced during the time period during which the flow agreement has been in effect was approximately 3,010 cfs. This average had occurred over two separate 7-day periods and was considered an appropriate critical low flow by both the Department and EPA Region 4. The revised draft TMDL is also based on this flow.

29. Comment: One commenter states that actual measured conditions should be used as critical condition model inputs, apparently regardless of how far outside the normal range of expected conditions they may be, and that use of less restrictive conditions would not be adequately protective.

Response: Predictive modeling for wasteload allocation and TMDL development is conducted to approach but not reach Aworst case@ conditions for a number of parameters including, but not limited to, flow, water temperature, point source loadings, background pollutant loading and meteorological conditions. A balance must be struck between evaluating discharges such that a reasonable level of protection is achieved but not determining limits based on a combination of conditions that could never simultaneously occur. EPA has evaluated the CHP TMDL modeling effort and reviewed all inputs including critical conditions. With the exception of adjustment of the nitrification rate, the inclusion of appropriate bottom friction values and assurance that the wind kinetics and marsh loadings were included in the critical condition model, the critical conditions selected by EPA for the predictive modeling are the same as those applied in the TMDL model. The level of protection is considered appropriate by the Department and EPA.

30. Comment: One commenter states that while it could be assumed that daily maximum limits are the basis for the ultimate oxygen demand (UOD) values given for the present and proposed limits, it was unclear and a more complete presentation of limits one would find in the permits was needed. Also, they state that it was unclear whether the permit values were monthly or weekly averages or daily maximum limits.

Response: UOD is a combination of carbonaceous and nitrogenous oxygen demand. The draft TMDL modeling effort is mainly concerned with the overall impact of oxygen demanding substances and less so with whether this demand comes from carbonaceous or nitrogenous demand. The draft TMDL is written in terms of overall demand with permittees limited by their overall impact on the river. Permits will be written to limit overall demand while allowing flexibility in how the nitrogenous and carbonaceous portions are treated. Through the permitting process, wasteload allocations developed through the TMDL process will be specified as monthly average limits. In addition to monthly average limits, appropriate daily maximum and weekly average limits may be included in permits per SC Regulation 61-9.

31. Comment: One commenter states that only general statements were made concerning implementation of the draft TMDL and that they believe implementation must be more specific and state the time period within which the finalized TMDL will be incorporated into existing and new permits.

Response: Current TMDL requirements do not include a detailed implementation plan as part of a final TMDL. Therefore, a detailed implementation plan is not incorporated into Cooper River draft TMDL. However, the revised draft TMDL does include an outline of the compliance schedule for phase 1 loadings that will be included in NPDES permits to be issued, final TMDL loadings that will become effective unless additional modeling work is done and a schedule for conducting the additional modeling work upon which alternate loadings may be based.

32. Comment: One commenter indicates that the shortnosed sturgeon uses the waters of the Charleston Harbor System and states that any TMDL that fails to provide adequate protection for this species would be unacceptable.

Response: Application of the 0.1 Rule will allow a de minimis lowering of dissolved oxygen levels in the Charleston Harbor System. Under critical conditions, the TMDL will allow a lowering of approximately one tenth of one part per million of dissolved oxygen below natural conditions and will be protective of the balanced indigenous aquatic community which includes the shortnosed sturgeon.

33. Comment: Numerous commenters express concern for the impact the draft TMDL requirements may have on the companies for which they work and future development and growth in the area. They further question the impact of the required treatment levels on sewer rates. The Department was urged to reconsider the new limits and set more realistic wastewater discharge levels that Awould balance the needs of the local economy with protection of the river.@

Response: The Department must take into account and address economic and social impacts of its regulations during the long process of regulation development, promulgation and approval by the legislature. Resulting regulations must be protective of water quality and its uses. The Department must abide by regulatory requirements in its issuance of wasteload allocations, TMDLs, and NPDES permits which implement those regulations. These activities include some consideration of the economic impact of a particular permit action, but the Department must protect existing uses and cannot allow these uses to be impaired based on economic considerations. The Department has worked closely with EPA and the municipalities and industries impacted by the Cooper River draft TMDL to ensure that it is a scientifically-defensible action that is consistent with the regulations and is necessary to protect water quality.

The following entities, both private and public, submitted comments on the initial Cooper River draft TMDL:

Bayer Corporation
Berkeley County Water and Sanitation Authority
BP Cooper River Plant
Charleston Metro Chamber
City of Charleston Commissioners of Public Works
Cooper River Water Users Association
Hunton & Williams
Low Country Manufacturing Council
North Charleston Sewer District
South Carolina Department of Natural Resources
Southern Environmental Law Center
Westvaco, Inc.
Thomas S. McGorty
Charles Thierfelder
Charles M. Walker
Dwayne Morris
Craig S. Faust
Troy Shaw
R. Glenn Butler
Michael S. LeClair
William D. Jones
Charlie N. Smith
Charles H. Martin
Edward P. Greenhill, Jr.
James C. Dunn
Roger L. Campsen
Larry L. Sieber

William D. Heidtman
Donna J. Hansen
Lunelle S. Allen
Raymond D. Allen
James M. Koches
Herman W. Stehmeier
Steven C. Patterson
Walter J. Wade
Grover F. Maherg
Ruford J. Bolchoz
Andrew L. Hunt
Jennifer Howard
Denny Cleanovic
D.A. Scheffing
Gene Hundley
Byron S. Toney
Charles and Celia Cobb
Alain Logerot
John J. Stuart
Fred Kinard
Herbert E. Dixon
James M. McSherry
Carl W. Bailey
Mark R. Jordan
Robert C. Flowe
Maria P. Brockenfelt
Gerald E. Brockenfelt
Karen L. Adair
David W. Gerhardt
Chris Vaughn
Eugene G. Parker
Elaine C. Newman
John C. Snowden
Donnell Van Noppen III
Robert Duncan
Steven Koorse
A.J. Batla
J. Marc Hehn
Robert M. Zimpfer
James D. Bradley
John P. Cook
Wilson T. Gautreaux
Jimmy L. Green

APPENDIX D

COG RECOMMENDED WASTELOAD ALLOCATIONS

BERKELEY-CHARLESTON-DORCHESTER COUNCIL OF GOVERNMENTS LETTER OF AUGUST 30, 2002

Table 1. Final (Phase 2) Critical Conditions TMDL Allocation

NPDES Loads **Charleston Harbor TMDL Calculator**

Discharger	NPDES	Flow	CBOD5		f-ratio	CBODU			NH3			UOD	Percentage
	Permit Number	mgd	mg/L	lbs/day		mg/L	lbs/day	g/s	mg/L	lbs/day	g/s	lbs/day	of Total
Monks Corner WWTF	SC0021598	3.2	30.0	801	1.5	45.0	1,201	6.31	20.0	534	2.80	3,640	6.329
Central BCW&SA	SC0039764	1	30.0	250	1.5	45.0	375	1.97	20.0	167	0.88	1,138	1.978
DAK Americas	SC0026506	1.322	21.5	237	3	64.4	710	3.73	1.0	11	0.06	761	1.322
Bayer	SC0003441	5.65	34.0	1600	3	101.9	4,800	25.20	12.7	600	3.15	7,542	13.112
City of Hanahan	SC0021041	0	0.0	0	1.5	0.0	0	0.00	0.0	0	0.00	0	0.000
BP Cooper River	SC0028584	4.23	21.1	743	3	63.2	2,229	11.70	0.0	0	0.00	2,229	3.875
Lower BCW&SA [3]	SC0046060	22.5	10.0	1,877	1.5	15.0	2,815	14.78	2.0	375	1.97	4,530	7.875
MeadWestvaco	SC0001759	25.6	17.2	3666	4	68.7	14,664	76.99	0.0	0	0.00	14,664	25.493
SC Ports	SC0021385	0.056	30.0	14	1.5	45.0	21	0.11	0.0	0	0.00	21.0	0.037
Daniel Island		4	5.0	167	1.5	7.5	250	1.31	1.0	33	0.18	402.7	0.700
North Charleston Sewer District [2]	SC0024783	34	10.0	2,836	1.56	15.6	4,424	23.22	2.0	567	2.98	7,015	12.196
Plum Island WWTP [1]	SC0021229	36	10.0	3,002	1.5	15.0	4,504	23.64	2.0	600	3.15	7,248	12.600
Center Street	SC0040771	3.7	30.0	926	1.5	45.0	1,389	7.29	20.0	617	3.24	4,209	7.317
Rifle Range	SC0040771	6	15.0	751	1.5	22.5	1,126	5.91	13.1	656	3.44	4,122	7.166
											TOTAL UOD =	57,521	100.0

Segment			***Cooper River Mouth to Goose Creek***					***Cooper / Wando Estuary***			
	UOD (#/day)		**Delta D.O. (mg/l)**		**% Delta D**	**factors**		**Delta D.O. (mg/l)**		**% Delta D**	**factors**
Monks Corner WWTF	3,640		0.006		3.7%	0.022		0.002		1.8%	0.0078
Central BCW&SA	1,138		0.002		1.3%	0.025		0.001		0.6%	0.0080
Dupont	761		0.003		1.6%	0.035		0.001		0.9%	0.0137
Bayer	7,542		0.022		14.0%	0.035		0.009		7.9%	0.0144
City of Hanahan	0		0.000		0.0%	0.040		0.000		0.0%	0.0200
Amoco	2,229		0.012		7.5%	0.054		0.005		4.4%	0.0230
Lower BCW&SA [3]	4,530		0.032		19.9%	0.084		0.014		12.4%	0.0377
Westvaco	14,664		0.065		40.2%	0.044		0.059		50.5%	0.0400
SC Ports	21		0.000		0.1%	0.040		0.000		0.1%	0.0400
Daniel Island	403		0.001		0.7%	0.035		0.001		1.2%	0.0410
North Charleston Sewer District [2]	7,015		0.014		8.4%	0.0228		0.025		21.5%	0.0420
Plum Island WWTP [1]	7,248		0.002		1.0%	0.003		0.007		6.3%	0.0120
Mt Pleasant	4,209		0.001		0.8%	0.004		0.003		2.8%	0.0106
Mt Pleasant	4,122		0.001		0.8%	0.004		0.003		2.6%	0.0106

UOD (#/day) = 57,521 Delta DO 0.137 mg/l 1.000 Delta DO = 0.116 mg/l 1.129

Table 2. Interim (Phase 1) Critical Conditions TMDL Allocation

NPDES Loads **Charleston Harbor TMDL Calculator**

Discharger	NPDES	Flow	CBOD5		f-ratio	CBODU			NH3			UOD	Percentage
	Permit Number	mgd	mg/L	lbs/day		mg/L	lbs/day	g/s	mg/L	lbs/day	g/s	lbs/day	of Total
Monks Corner WWTF	SC0021598	3.2	30.0	801	1.5	45.0	1,201	6.31	20.0	534	2.80	3,640	4.660
Central BCW&SA	SC0039764	1	30.0	250	1.5	45.0	375	1.97	20.0	167	0.88	1,138	1.456
DAK Americas	SC0026506	1.322	21.5	237	3	64.5	711	3.73	1.0	11	0.06	762	0.975
Bayer	SC0003441	5.65	34.0	1600	3	101.9	4,800	25.20	12.7	600	3.15	7,542	9.654
City of Hanahan	SC0021041	0	0.0	0	1.5	0.0	0	0.00	0.0	0	0.00	0	0.000
BP Cooper River	SC0028584	4.23	21.1	743	3	63.2	2,229	11.70	0.0	0	0.00	2,229	2.853
Lower BCW&SA [(3)]	SC0046060	22.5	20.0	3,753	1.5	30.0	5,630	29.55	3.0	563	2.96	8,202	10.499
MeadWestvaco	SC0001759	25.6	23.4	5000	4	93.7	20,000	105.00	0.0	0	0.00	20,000	25.600
SC Ports	SC0021385	0.056	30.0	14	1.5	45.0	21	0.11	0.0	0	0.00	21.0	0.027
Daniel Island		4	5.0	167	1.5	7.5	250	1.31	1.0	33	0.18	402.7	0.515
North Charleston Sewer District [(2)]	SC0024783	34	20.0	5,671	1.56	31.2	8,847	46.45	3.0	851	4.47	12,735	16.300
Plum Island WWTP [(1)]	SC0021229	36	20.0	6,005	1.5	30.0	9,007	47.29	3.0	901	4.73	13,123	16.798
Center Street	SC0040771	3.7	30.0	926	1.5	45.0	1,389	7.29	20.0	617	3.24	4,209	5.388
Rifle Range	SC0040771	6	15.0	751	1.5	22.5	1,126	5.91	13.1	656	3.44	4,122	5.276
											TOTAL UOD =	78,125	100.0

Segment			***Cooper River Mouth to Goose Creek***					***Cooper / Wando Estuary***			
	UOD (#/day)		**Delta D.O. (mg/l)**		**% Delta D**	**factors**		**Delta D.O. (mg/l)**		**% Delta DC**	**factors**
Monks Corner WWTF	3,640		0.006		2.6%	0.022		0.002		1.1%	0.0078
Central BCW&SA	1,138		0.002		0.9%	0.025		0.001		0.4%	0.0080
Dupont	762		0.003		1.2%	0.035		0.001		0.6%	0.0137
Bayer	7,542		0.022		10.0%	0.035		0.009		5.2%	0.0144
City of Hanahan	0		0.000		0.0%	0.040		0.000		0.0%	0.0200
Amoco	2,229		0.012		5.4%	0.054		0.005		2.9%	0.0230
Lower BCW&SA [(3)]	8,202		0.060		26.6%	0.084		0.027		15.1%	0.0377
Westvaco	20,000		0.088		39.1%	0.044		0.080		44.9%	0.0400
SC Ports	21		0.000		0.0%	0.040		0.000		0.0%	0.0400
Daniel Island	403		0.001		0.5%	0.035		0.001		0.8%	0.0410
North Charleston Sewer District [(2)]	12,735		0.025		11.3%	0.0228		0.047		26.2%	0.0420
Plum Island WWTP [(1)]	13,123		0.003		1.4%	0.003		0.014		7.7%	0.0120
Mt Pleasant	4,209		0.001		0.6%	0.004		0.003		1.8%	0.0106
Mt Pleasant	4,122		0.001		0.5%	0.004		0.003		1.7%	0.0106
UOD (#/day) =	**78,125**	**Delta DO =**	**0.202**	**mg/l**	**1.000**	**Delta DO =**		**0.178**	**mg/l**	**1.084**	

APPENDIX E

TETRA TECH, INC. MODELING DOCUMENT
MAY 6, 1998

TETRA TECH, INC.
10306 Eaton Pl Suite 340
Fairfax, VA 22030
Telephone (703) 385-6000

RECEIVED

MAY 11 1998

BUREAU OF WATER
WATER QUALITY DIVISION

May 6, 1998

Mr. Chris Laabs
U.S. EPA
499 South Capital Street
Washington, D.C. 20024

Dear Chris:

Enclosed is the revised response to the South Carolina TMDL SWAT request. The revision was based on comments received from EPA and South Carolina Department of Health and Environmental Control staffs. If you have questions about the content of this report, please feel free to call me at (703) 385-6000. Thanks.

Sincerely,

John P. Craig
Environmental Scientist

cc: Jim Greenfield, EPA Region 4
Larry Turner, SC DHEC

Review of South Carolina Dynamic Modeling Applications for Dissolved Oxygen

Jonathan B. Butcher, Ph.D., P.H.
Tetra Tech, Inc.
May 6, 1998

1. Summary

Through the EPA SWAT program, the South Carolina Department of Health and Environmental Control (DHEC) requested a review of their application of dynamic modeling to wasteload allocation development for biochemical oxygen demand (BOD) and ammonia loading in terms of their impacts on dissolved oxygen (DO). This report is based on a review of two draft wasteload allocation model applications to the Waccamaw River/Intracoastal Waterway system and to the Cooper/Wando River system.

DHEC specifically requested an assessment of (1) the appropriateness of using dynamic models to determine wasteload allocations, (2) the methodology used to determine critical conditions, (3) the averaging period used to evaluate model output for compliance with standards, and (4) the methodology used to determine permit limits from model output. In general these applications are of high quality and relevant to establishing appropriate wasteload allocations. The following summarizes the results of the review:

- Dynamic models of the type used by DHEC are appropriate for wasteload allocations in tidal systems.

- Critical conditions used in the existing wasteload allocation applications might be overly stringent. Additional analysis of critical conditions for determination of wasteload allocations might hold excursions of the DO standard to an acceptably low frequency.

- Consideration might be given to the use of a fixed daily period (rather than running a twenty-four hour average) for evaluation of the daily average instead of 7-day average concentrations. In addition, evaluation of dynamic model output both in terms of instantaneous concentrations (for compliance with the instantaneous DO standard) and daily average concentrations (for compliance with the daily average standard) would coordinate with the state water quality standards.

- A statistical method can be used to evaluate the consistency of permit limits with the wasteload allocations.

2. Relevant Standards

In wasteload allocations, models are applied to determine and predict attainment of water quality standards. Therefore, appropriate model application and interpretation of model output is consistent with the applicable state standards. South Carolina standards are summarized in this section.

DO Standards

Dynamic models of the DO balance are proposed by DHEC for analysis of waterbodies in which steady state and tidally averaged models may lead to an incomplete or incorrect evaluation of the impacts of loads of oxygen demanding waste. This includes estuarine and tidally-influenced freshwater rivers, as well as rivers controlled by hydroelectric power plants. The most relevant South Carolina water use classifications in which dynamic models are likely to be applied for wasteload allocations are Freshwaters ("freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment..."), Class SA ("tidal saltwaters suitable for primary and secondary contact recreation"), and Class SB ("tidal saltwaters suitable for primary and secondary contact recreation, crabbing and fishing, except harvesting of clams, mussels, or oysters for market purposes or human consumption"). Within Freshwaters and Class SA waters, the following quality standard is established for DO: "Daily average not less than 5.0 mg/l with a low of 4.0 mg/l." Within Class SB waters the standard for DO oxygen is "not less than 4.0 mg/l."

Applicability of Standards

These standards are not applied under extreme low flow conditions. The general statement on applicability at C(2)(a) and (b) states:

> (a) With the exception of human health criteria...the numeric standards...are applicable to any flowing waters when the flow rate is equal to or greater than the minimum seven day average flow rate that occurs with an average frequency of once in ten years (7Q10).
> (b) The Department will consider flows other than 7Q10 where appropriate to protect classified and existing uses.

In addition, South Carolina's antidegradation statement at D(4) provides for water bodies in which the DO concentration will naturally contravene the standards (the "point one" rule):

> Under certain conditions, the quality of some free flowing surface waters and lakes... does not meet numeric standards for dissolved oxygen due to natural conditions, even though classified uses in these waters are achieved. Under these conditions, the quality of the free flowing surface waters or lakes...shall not be cumulatively lowered more than 0.10

mg/l for dissolved oxygen from impacts by point sources and other activities, unless a site-specific standard is established.

Comments

The regulations state that 4 mg/l is an instantaneous minimum standard for DO and the 5 mg/l standard (applicable to Freshwaters and Class SA waters) is defined as a daily average.

The applicability statement recognizes that appropriate DO standards are likely to be contravened under rare conditions of extreme low dilution. The intent of the standard is not to ensure that instantaneous DO concentrations less than 4 mg/l (and daily average concentrations less than 5 mg/l) *never* occur; rather, it is to ensure that excursions of the standard are held to an acceptably low frequency. In flowing streams this goal is achieved by specifying that the standards are applicable only when flow is equal to or greater than the 7Q10 flow; it is expected that a low (but non-zero) frequency of excursions will occur during those infrequent time periods when flow is less than 7Q10.

The 7Q10 flow is established as a cutoff value of flow rate for applicability of the standards. Even though this flow rate is estimated as a 7-day average, no averaging period for applicability of the standard is necessarily implied by use of the 7Q10 calculation. For instance, analysis of historical flow records might establish that the 7Q10 flow for a given river is 100 cfs. Instantaneous standards (e.g., 4 mg/l DO) should then be achieved whenever the instantaneous flow is greater than 100 cfs. Two interpretations appear possible for daily average standards (e.g., 5 mg/l DO): (1) the standard should be achieved as a daily average whenever the daily average flow is greater than 100 cfs; or (2) the standard should be achieved as the daily average of all times in which the instantaneous flow is greater than 100 cfs. These two interpretations can yield different results when continuous observations or model predictions of DO are available. The first alternative is more stringent, as DO concentrations at flows less than 7Q10 may be included in a daily average, as long as the daily average flow is greater than or equal to the 7Q10 flow. For instance, consider a river with a 7Q10 of 100 cfs and 24-hour period in which 12 hours of flow are at 50 cfs and a DO of 3 mg/l and 12 hours of flow are at 150 cfs and a DO of 5 mg/l. The daily average flow is equal to the 7Q10 flow. The first interpretation of applicability yields a daily average DO concentration of 4 mg/l. The second interpretation, which allows exclusion of the 12 hour period with flow less than 7Q10, yields a daily average concentration of 5 mg/l for purposes of application of the standard. The issue is not, however, relevant to the "critical condition" model applications submitted by DHEC as long as boundary flows are held at appropriate design conditions.

The "point one" rule in the antidegradation statement does not contain a specific note as to applicable flow conditions. However, since the "point one" rule refers to conditions in which standards are not achieved, and standards are only applicable at flows greater than or equal to the

7Q10 flow, the "point one" rule also can be inferred to be applicable at flows greater than or equal to the 7Q10 flow.

The applicability clause is written for uni-directional flowing streams in which the 7Q10 flow is readily determined. In tidal systems, 7Q10 may not be readily measured, and the interpretation is much less clear. The intent of the standards appears clear, however, that allocations for these types of waterbodies should be designed to restrict excursions of the DO standard to an acceptably low frequency, rather than prohibiting excursions under all extreme low dilution conditions. Potential minimum dilution design conditions for tidal systems are discussed further in Section 5.

3. Use of Dynamic Models for Wasteload Allocations

Applicability of Dynamic Models to DO Analysis in Tidal Systems

In wasteload allocations, models are applied to determine and predict attainment of water quality standards. Therefore, appropriate model application and interpretation of model output should be consistent with the applicable state standards. Traditionally, most wasteload allocations have relied on steady state modeling at design conditions representative of a rare event with a specified probability of occurrence. Where appropriate, steady state models are recommended for wasteload allocations because they are simpler to apply and easier to interpret. In certain situations, however, steady state modeling does not provide an accurate estimate of the probability of excursions of a standard resulting from a wasteload allocation. The steady state approach yields only the probability of standard excursions at design conditions, and does not yield the full distribution of environmental outcomes. This is appropriate when a design condition associated with an acceptable low probability of excursion of the standard is identifiable—for instance, when an effluent discharges oxygen-demanding waste into a uni-directional flowing stream, such that impact on DO is at a maximum when dilution capacity is lowest, temperature-dependent oxygen saturation is lowest, and temperature-dependent reaction rates are highest. To determine design or critical conditions, a suitably rare combination of low dilution flow, high water temperature, and other relevant factors is selected. A steady state wasteload allocation at such design conditions then ensures that excursions of the standard will not occur at more common higher flow and lower temperature combinations. If, however, a design condition is not identifiable, steady state wasteload allocations under a particular set of conditions cannot ensure a specific low frequency of excursions of the standard under other conditions. Use of steady state models also does not explicitly consider the effects of correlation between dilution capacity and variable effluent loads. For instance, precipitation-driven nonpoint loads are associated with higher instream dilution flows, and analysis at steady state 7Q10 design conditions can lead to overly-stringent results.

For tidal waterbodies, flow is not uni-directional, but changes in magnitude and oscillates with the tidal cycle. It is still possible to define critical, minimum dilution conditions within a tidal system (see Section 4); however, a steady state analysis at the minimum dilution condition is not sufficient to provide an accurate time course prediction of DO concentrations, because DO will depend on the extent of mixing of oxygen-demanding waste in the period leading up to the minimum dilution condition, and critical DO concentrations may not coincide in time with minimum dilution.

In contrast to a steady state analysis, dynamic modeling approaches attempt to reproduce the actual time series or distribution of instream concentrations and explicitly include the effects of variability in dilution capacity and effluent load over time. A full dynamic modeling analysis can predict the entire effluent concentration frequency distribution, thus allowing wasteload allocations to be set to produce an expected frequency of excursions of the standard.

Steady state analyses are still useful for tidal systems, particularly for initial scoping analyses. They are particularly useful for approximating concentrations averaged over a tidal cycle. For DO problems a steady state analysis cannot, however, provide accurate estimates of intra-tidal instantaneous concentrations. South Carolina water quality standards specify both daily average and instantaneous DO concentrations. Thus, a dynamic, intra-tidal modeling analysis is appropriate for accurate determination of a wasteload allocation.

DHEC Dynamic Model Applications

For two waterbodies—the Waccamaw/Intracoastal Waterway and the Cooper River—DHEC, in conjunction with USGS, has conducted dynamic DO modeling using the BRANCH/BLTM model (Drewes and Conrads 1995, Conrads and Smith 1997). BRANCH/BLTM is a USGS one-dimensional, unsteady-flow model coupled with an unsteady water-quality transport model which is applicable to tidal systems lacking significant stratification. Both models have a credible record of application by USGS and others. DO and nutrient kinetics of the BLTM model are the same as those included in EPA's QUAL2E model.

A technical review of model application was not specifically requested for this SWAT response; however, a cursory review of the model set-up and calibration did not uncover any unreasonable assumptions. Synoptic water quality data available for calibration were, however, limited. The Waccamaw/Intracoastal Waterway model was calibrated to data for April 10-25, 1990, while the Cooper/Wando model was calibrated to data for August 23-25, 1993 and validated on data from May 4-5, 1993. For the Waccamaw/Intracoastal Waterway system, USGS developed assimilative capacity curves that show assimilative capacity conditional on seven-day average influent streamflows. For the Cooper/Wando model, the primary freshwater input is controlled by Pinopolis Dam, and USGS reported simulations for several different assumptions of flow over this dam.

One significant difference between the Cooper and Waccamaw models is that the Cooper model includes algae in the simulation, while the Waccamaw model does not. This is typically a difficult issue for DO wasteload allocation modeling. Algae can have a significant effect on the DO balance, but are difficult to represent accurately in dynamic models. Under many conditions algae lead to a net increase in DO; however, at a saltwater/freshwater interface the die-off of freshwater algae can sometimes result in a high oxygen demand. It is often necessary to include algae in a DO model to obtain calibration to synoptic data, unless the effect of algae on the DO balance can be shown to be insignificant. Inclusion of algae in a wasteload allocation model is a different matter. While algae may increase DO during calibration observations, algal populations are highly variable, and may not always mitigate effects of oxygen-demanding waste. An available option to account for the effects of algae but still ensure the highest possible accuracy, is to calibrate and validate the model including the algal component, but then run the model with and without algae, using the more stringent result for the wasteload allocation.

4. Interpretation of Dynamic Modeling Output: Averaging Periods

DHEC extended the USGS model applications for the Waccamaw and Cooper Rivers by adjusting the calibrated, validated BRANCH model to a critical conditions model. First, assumptions were made for design conditions of flow and other relevant parameters (see Section 5 for a review of design condition assumptions). For the Waccamaw, the analysis was based on examination of the June to September flow records for the year of calibration, with the most critical month selected for each permitted facility (September for some, July for others). For the Cooper river the model uses an observed late summer month of flow conditions, except that some synthesized flows are used for the dam. The last two weeks of the simulation period is at dam releases equal to the limiting flow specified in the dam operation agreement (personal communication from Nancy Sullins, SC DHEC, 1/12/98). In both water bodies the DO standards are not expected to be attained due to natural conditions at low flow conditions, so the "point one" rule is applied to analysis of wasteload allocations. DHEC then applied the model as follows:

> DHEC has chosen to run the BRANCH/BLTM model for six weeks, two weeks for model warm up and four weeks of the critical month. First, a no load run is made without discharger inputs. Then the model is run with the dischargers permitted loads included. The outputs are compared, time step by time step, and twenty-four hour running averages of the differences between the two scenarios are determined. Adjustments are made in the "with load" scenario to determine the maximum loading that will not result in any twenty-four hour period having an average deficit greater than 0.1 mg/l. The load associated with this 0.1 mg/l change is then identified as the maximum allowable load for that reach of the water body. A twenty-four hour running average was chosen with the thought that any averaging period longer than twenty-four hours would reduce the variability of the predicted dissolved oxygen. This softening of the curve reduces the

effectiveness of the model to predict periods which may cause stress to the biological community.

The DHEC analysis of attainment of standards is based on running twenty-four hour averages calculated from a critical low flow month, with other design conditions held constant. Instantaneous predictions were not used to assess attainment.

Examination of issues surrounding the averaging period was included in review of the analysis. The water quality standards express an instantaneous DO standard (4 mg/l) and a "daily average" DO standard (5 mg/l). Therefore, for waters which would attain the standards under natural conditions, it would be appropriate to compare both each instantaneous prediction and the twenty-four hour averages in model output to the appropriate standard.

Similarly, in naturally non-attaining waters where the "point one" rule applies, both instantaneous and daily average values are appropriate for measurement to compare to the water quality standards. For any point in time when the instantaneous DO under natural conditions would be less than 4 mg/l the wasteload allocations allows no more than an 0.1 mg/l lowering of instantaneous concentration, and for any day in which the average DO under natural conditions would be less than 5 mg/l the wasteload allocations allows no more than an 0.1 mg/l lowering of the twenty-four hour average concentration.

Options for calculation of the twenty-four averages include use of a running average, or use of a discrete average concentration over a specified diurnal cycle (e.g., sunrise to sunrise). The two methods do not necessarily provide the same result under dynamic conditions, and the running average would be more stringent, as it can "seek out" and combine adjacent parts of two days in which concentration is abnormally low. However, the use of running twenty-four hour averages may overestimate the accuracy of the model. In general, DO models should be better at predicting the average over a diurnal cycle than instantaneous concentrations. Therefore, it might be more appropriate to evaluate daily averages on a fixed (rather than running) twenty-four hour period.

According to DHEC, "There has been concern expressed by the regulated community that the twenty-four hour running average is overly conservative and a seven day average is more appropriate for tidally influenced systems." The South Carolina standards refer to the twenty-four hour average and minimum concentrations and not a 7-day average. The fact that the flow regime under which the standard is applicable is based on the 7Q10 flow is not relevant to the standard averaging period. Finally, it should be noted that the appropriate interpretation of dynamic model output is dependent on how the design conditions are specified. These issues are addressed in the following section.

5. Design Conditions for Dynamic Modeling

Dynamic versus Quasi-Dynamic State Applications

For tidal systems, dynamic modeling of DO is recommended to capture complex patterns induced by tidal mixing, particularly for prediction of instantaneous DO concentrations. DHEC adopted a dynamic modeling framework primarily because appropriate design conditions for flow in tidal systems were not readily identifiable. Model calibration to synoptic data also implicitly includes the effects of variability in nonpoint and background pollutant loads, although this is not explicitly addressed in the wasteload allocation applications.

As noted above, a full dynamic modeling analysis can predict the entire effluent concentration frequency distribution, thus allowing wasteload allocations to be set to produce an expected frequency of excursions of the standard. A full dynamic analysis, however, requires a substantial level of effort and data. For instance, if recurrence intervals of 10 or 20 years are desired, at least 30 years of continuous simulation is needed to provide a sufficient record to estimate the probability of such rare events (USEPA 1991).

While DHEC has employed a dynamic model, the wasteload allocation procedure is not a full dynamic analysis; sufficient flow data are not available to undertake long-term simulation. Instead, DHEC has used the dynamic model to represent internal flow and mixing processes, and to implicitly determine critical flow conditions. The wasteload allocation analysis was then performed with other critical conditions, such as temperature, held constant. This may be termed a quasi-dynamic model application. Although based on dynamic flows, it is still essentially a design condition analysis.

This section reviews the various components of the quasi-dynamic design condition specification.

Approximate Minimum Dilution Design Conditions for Tidal Systems

In typical steady state wasteload allocation modeling, a design low flow such as the 7Q10 is used. This design flow has a low dilution capacity for effluents, and is used to implicitly establish an acceptable frequency of excursions of the standard associated with a wasteload allocation for a steady source. Within tidal systems, the concept of 7Q10 flow does not directly apply, although a 7Q10 flow of freshwater influent to the tidal system can be estimated. More importantly, dilution capacity of a tidal system is a function of both the inflow of fresh water and tidal flushing.

DHEC has adopted a quasi-dynamic modeling approach to represent tidally-driven mass fluxes and intratidal variability of concentrations within the waterbody. Boundary conditions are held constant in the quasi-dynamic application. Because simulation is not undertaken for the long period of time necessary to establish actual average excursion frequencies, it is important to ensure that the simulation design conditions represent a suitable level of criticality in dilution capacity. A steady-state analysis would be sufficient to establish wasteload allocations. Although more than one option might be appropriate, an example approach for tidal systems is to use an analysis based on a minimum dilution level which is analogous to the 7Q10 flow used for steady state wasteload allocations in streams. USEPA (1991, p.74) makes the following recommendation for estimating critical dilution conditions for toxics in estuaries:

> In estuaries without stratification, the critical dilution condition includes a combination of low-water slack at spring tide for the estuary and design low flow for riverine inflow. In estuaries with stratification, a site-specific analysis of a period of minimum stratification and a period of maximum stratification, both at low-water slack, should be made to determine which one results in the lowest dilution... Recommendations for a critical design period for coastal bays are the same as for stratified estuaries.

This approach is most applicable to acute or instantaneous standards for toxics in which intra-tidal variability must be considered and maximum impact is expected at the point of discharge of an effluent. For BOD/DO problems, reactions and transport within the system must also be considered and maximum DO deficit may not coincide in time with minimum dilution; it would be advisable to examine a combination of design low flow (7Q10) in riverine inflow with both spring and neap tidal ranges, which determine the maximum and minimum values of tidal mixing. With this approach, it would be helpful to examine instantaneous DO concentrations and daily average conditions over a full lunar cycle.

Physical and Chemical Components of Design Conditions

A number of factors other than flow or dilution capacity affect the impact of BOD loads on DO concentrations. Most notable among these is temperature: higher temperatures decrease the saturation concentration of oxygen in water, and increase reaction rates which deplete DO. The DO balance is also affected by wind-driven reaeration and influent (freshwater or tidal) concentrations of DO, BOD, and nutrients (which affect algal growth and thus DO). Design conditions for DO/BOD analysis should specify a variety of other physical and chemical factors in addition to flow. This is done automatically in a full dynamic simulation; in the quasi-dynamic approach, fixed boundary values of these supplementary parameters are specified externally. While using a dynamic simulation of flows, DHEC has specified additional critical conditions as steady state at the boundaries using the following rule:

> In-stream water temperature, DO, NH_3-N, NO_2, NO_3, PO_4, and BOD_5 critical values are determined by identifying the 95th percentile of all parameters except for DO, where the 5th percentile was identified, for the given month from STORET station monthly

sampling data located within the model's domain. These percentiles were chosen with the thought that since a 7Q10 critical flow period approximates a 95th percentile the other parameters should approach the same criticality.

The 7Q10 critical flow does not specifically represent a "95^{th} percentile." The 7Q10 is calculated as a minimum annual 7-day average which recurs once every ten years on average—so, on average, one or more 7-day flows at least this low will be seen in one out of ten years (10% of years). The 7Q10 is based on annual minima, and is not simply related to the actual frequency of 7-day flows. In the terminology of USEPA (1986), the 7Q10 is a hydrologically-based recurrence interval, whereas the actual recurrence of all low dilution flows (not just annual minima) is called a "biologically-based" recurrence interval. Further, the South Carolina standards are based on 1-day or instantaneous flows, not 7-day flows, even though the 7Q10 is used to establish the critical flow. Based on the analysis in USEPA (1986), the 1-day biologically-based dilution flow with a 3-year recurrence interval averages approximately 90% of the 7Q10 flow. Therefore, a 1-day flow at the 7Q10 value should occur in *at least* one out of three years, only 0.09% of days.

A second concern is that if a 95^{th} (or other) percentile level is desired, this is not properly obtained by taking the 95^{th} percentile value of each of seven observed parameters, unless the distributions of these parameters are perfectly correlated. For example, assume that each of the parameters is independent. For each parameter, a value equal to or greater than the 95^{th} percentile occurs 5% of the time. The probability of all seven parameters exceeding the 95^{th} percentile at the same time (if independently distributed) would be $0.05^7 = 7.81 \times 10^{-10}$, or the 99.9999999^{th} percentile. Even for three parameters (e.g., temperature, DO, and BOD, as required for the Waccamaw model), the probability of all parameters exceeding the 95^{th} percentile (if independently distributed) is equal to the 99.9875^{th} percentile. Although, some of these parameters will be strongly correlated (e.g., the nitrogen series), increasing the probability of co-occurrence. Others, however, (such as temperature and BOD_5) may be negatively correlated, which decreases the probability of co-occurrence. Further, the analysis assumes that the 95^{th} percentile of these parameters is uncorrelated to the occurrence of minimum flow, whereas nonpoint washoff processes may result in a positive relationship between flow and pollutant concentrations, and perhaps a negative correlation between flow and temperature.

Determining appropriate critical conditions for multiple parameters is a difficult issue. It is possible, however, that choosing the 95^{th} percentile (5^{th} percentile for DO) of each of these parameters could lead to an analysis which is more stringent than is intended. Indeed, if analysis with the 7Q10 dilution flow is assumed to implicitly establish an allowed frequency of excursion of the standard, selection of extreme values for other design conditions would result in holding the allocations to a lower allowed frequency of excursions than is implied in the regulation. Unfortunately, the fact that the distributions are likely to be non-normal and correlated means that an analysis with the other design conditions simply set to monthly mean values may underestimate the actual frequency of excursions.

There are various approaches which can be taken here. One is to impose a protective, but more conservative assumption. For instance, the State of North Carolina sets each of these auxiliary design parameters at the outer edge of the interquartile range (75th or 25th percentile) of the observed summer distribution in a wasteload allocation. This is essentially an *ad hoc* compromise designed to avoid highly stringent results while retaining a (likely) conservative approach. This percentile was selected based on non-parametric analysis which suggested it provided a good representation of the actual frequency of excursions of standards (personal communication from Trevor Clements, former Chief, Technical Support Branch, Water Quality Section, NC Division of Environmental Management, now with Tetra Tech, 1/13/98).

A more rigorous alternative to specifying steady design boundary conditions is to undertake a multivariate analysis. This is the approach used in EPA's (1988, 1991) DESCON model. While DESCON is not directly applicable to tidal systems, the general approach is relevant. DESCON estimates design conditions based on maintaining a specified desired limit on the frequency of water quality excursions in a receiving water. DESCON considers the effects that daily fluctuations in stream flow and other water quality conditions have on the capability of a receiving water to accept pollutant loadings, while explicitly accounting for the correlation present among design variables. The general approach is as follows (USEPA 1991):

1. A long-term record of observed stream flows and pertinent water quality data are assembled or synthesized.

2. The maximum allowable pollutant load that the receiving water can accept without causing a water quality excursion is computed for each day of this record.

3. This synthesized record of allowable loads is searched for the critical load, i.e., the load whose frequency of not being exceeded matches the desired water quality excursion frequency.

4. Design conditions are then derived from receiving water conditions realized during the period of record when the computed allowable load was closest to the critical load.

Unfortunately, this type of approach would be difficult to implement for the complicated tidal flow patterns of the Waccamaw and Cooper Rivers. Further, available data might not be sufficient to support such an approach. Therefore, a simpler *ad hoc* approach (such as choosing 75th percentile values) is a more viable option.

However, a full long-term dynamic simulation would avoid these issues by directly representing the interactions between all parameters.

Based on the discussion on the previous pages, the following options for additional design or critical condition analysis are provided:

- Set upstream uncontrolled freshwater inflows to 7Q10 flows, consistent with state regulations to represent minimum dilution design conditions while keeping a dynamic seaward boundary condition. For Pinopolis Dam, set overflows to minimum specified in operational agreement.

- Select seaward tidal boundary conditions to represent the range of spring to neap tides. This is probably best done by simulating a lunar month (from first quarter to subsequent first quarter) with the addition of a sufficient model spin-up period.

- Set seaward boundary temperature and constituent concentrations to 75th percentile values (25th percentile for DO).

- Set freshwater inflow temperature and concentration to *either* median observed at low flow conditions, *or* 75th percentile values for summer months.

- Test sensitivity of model to boundary conditions.

6. Permit Limits

The procedure set out by DHEC yields wasteload allocations to result in compliance with the "point one" antidegradation rule. Appropriate statistical methods are discussed in EPA's (1991) TSD for Toxics. This approach to statistically-based permit limits is included as a point of discussion. It is not often applied to DO/BOD problems, but does represent a way to obtain sophisticated and accurate permit limits appropriate to dynamic model output. Other options are available that are appropriate for determining permit limits.

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APPENDIX F

EPA SENSITIVITY ANALYSIS REPORT

REVIEW OF THE DOCUMENT
REVIEW OF KEY MODEL INPUTS AND SENSITIVITY ANALYSIS FOR TMDL SIMULATIONS USING THE TWO-DIMENSIONAL WQMAP WATER QUALITY AND HYDRODYNAMIC MODEL DEVELOPED FOR THE CHARLESTON HARBOR SYSTEM

JIM GREENFIELD, EPA REGION 4
APRIL 2002

Mr. Alton Boozer May 2, 2002

Chief, Bureau of Water

South Carolina Department of Health

And Environmental Control

2600 Bull Street

Columbia, South Carolina 29201

Dear Mr. Boozer:

I have completed my review of the ATM *Review of Key Model Inputs and Sensitivity Analysis for TMDL Simulations* using the two-dimensional WQMAP Water Quality and Hydrodynamic model developed for the Charleston Harbor System.

EPA's conclusion is still that the existing 2D WQMAP model used to develop the proposed TMDL for oxygen-demanding wastes for the Charleston Harbor System is a technically defensible model and is acceptable for calculating the TMDL and wasteload allocations for point sources discharging to the Charleston Harbor System at non-wet weather critical conditions. The concerns raised in the sensitivity analysis may be valid, but the majority these concerns were or should have been addressed during the model calibration process. The TMDL model is based on the 1993 and 1996 calibration models and examining the sensitivity of the TMDL model without evaluating the impacts on the calibration models is not a valid modeling approach. These issues must be addressed when developing the calibration model, not during the TMDL development stage and should have been presented in the calibration report.

One item the sensitivity report did point out is that there is considerable uncertainty in the 2-D Charleston Harbor Model. Based on the TMDL regulations, the TMDL must contain a margin-of-safety to address this uncertainty. Options for addressing the model uncertainty is either assigns an explicit margin of safety based on the sensitivity analysis or incorporates an implicit margin of safety by using reasonably conservative modeling parameters and critical conditions. The EPA and SCDHEC TMDL model incorporates the implicit margin-of-safety approach by the selection of conservative modeling parameters and critical conditions. In my opinion, the use of other modeling parameters and critical conditions as indicated in the sensitivity report, would have required the use of an explicit margin-of-safety because of the demonstrated model uncertainty, and the resulting TMDL would have been similar.

If additional data are collected and a new or updated calibration model is made available based on new relevant data or information, then EPA and SCDHEC can revisit the TMDL modeling. A data collection plan similar to the 1999 Savannah Harbor data collection should be implemented to collect the adequate data necessary to calibrate a 3-D model. The resultant well calibrated, with limited uncertainty, 3-D hydrodynamic model and water quality model can be developed to address both the non-wet weather and wet weather non point source TMDL issues. Until this happens, I still recommend using the existing model for wasteload allocation purposes.

If you have questions regarding the attached review, or if I can be of further assistance, please call me at 404/562-9238.

Sincerely,

James Greenfield,
Senior TMDL Modeler
Water Management Division

Review of the

Review of Key Model Inputs and Sensitivity Analysis for TMDL Simulations using the two-dimensional WQMAP Water Quality and Hydrodynamic model developed for the Charleston Harbor System

Jim Greenfield, EPA Region 4

April 2002

BACKGROUND:

The Applied Technology & Management's (ATM) *Review of Key Model Inputs and Sensitivity Analysis for TMDL Simulations* using the two-dimensional WQMAP Water Quality and Hydrodynamic model developed for the Charleston Harbor System. The report attempts to demonstrates how changes to key modeling inputs can change the level of predicted dissolved oxygen in the harbor system.

EPA reviewed the above mentioned report and EPA's conclusion is still that the existing 2D WQMAP model used to develop the proposed TMDL for oxygen-demanding wastes for the Charleston Harbor System is a technically defensible model and is acceptable for calculating the TMDL and wasteload allocations for point sources discharging to the Charleston Harbor System at non-wet weather critical conditions. The concerns raised in the sensitivity analysis may be valid, but the majority these concerns were or should have been addressed during the model calibration process. The TMDL model is based on the 1993 and 1996 calibration models and examining the sensitivity of the TMDL model without evaluating the impacts on the calibration models is not a valid modeling approach. These issues must be addressed when developing the calibration model, not during the TMDL development stage and should have been presented in the calibration report.

One item the sensitivity report did point out is that there is considerable uncertainty in the 2-D Charleston Harbor Model. Based on the TMDL regulations, the TMDL must contain a margin-of-safety to address this uncertainty. Options for addressing the model uncertainty is either assigns an explicit margin of safety based on the sensitivity analysis or incorporates an implicit margin of safety by using reasonably conservative modeling parameters and critical conditions. The EPA and

SCDHEC TMDL model incorporates the implicit margin-of-safety approach by the selection of conservative modeling parameters and critical conditions. In my opinion, the use of other modeling parameters and critical conditions as indicated in the sensitivity report, would have required the use of an explicit margin-of-safety because of the demonstrated model uncertainty, and the resulting TMDL would have been similar.

If additional data are collected and a new or updated calibration model is made available based on new relevant data or information, then EPA and SCDHEC can revisit the TMDL modeling. A data collection plan similar to the 1999 Savannah Harbor data collection should be implemented to collect the adequate data necessary to calibrate a 3-D model. The resultant well calibrated, with limited uncertainty, 3-D hydrodynamic model and water quality model can be developed to address both the non-wet weather and wet weather non point source TMDL issues. Until this happens, I still recommend using the existing model for wasteload allocation purposes.

POINT BY POINT REVIEW OF KEY MODELING INPUTS

1) *The two-dimensional model is not suitable for application using the SCDHEC requirements since the range of uncertainty of the model predictions well exceeds 0.1 mg/l. Additionally, the over-prediction of dissolved oxygen impacts caused by the assumption of two-dimensional circulation becomes an error on the same order as the predicted impact when applying the 0.1 mg/l rule. The results of the three-dimensional model indicated, that using the same inputs as the above two-dimensional model simulation, the change in dissolved oxygen levels was only 0.05 mg/l. The three dimensional model was not calibrated, but the simulation does provide a demonstration of the very conservative nature of the two dimensional model and the difficulty in its application for predicting dissolved oxygen changes as small as 0.1 mg/l.*

   It is not valid to compare a non-calibrated 3-D model to the existing calibrated 2-D model. Because of the nature and additional complexity of the 3-D model the hydrodynamic driving functions will be different and unless the 3-D model is calibrated to the same data sets and conditions this exercise is meaningless.

2) *Horizontal Dispersion Rate – This rate is part of the process the model uses to simulate transport and mixing of loads in the river. The rate of 0.05 assigned for*

use in the Charleston Harbor System, dictated by computer limitations (larger coefficients require smaller time steps), is ultra conservative. Comparison with studies performed in Naples Bay, Florida indicate that rates as high as 11.0 have been shown to be reasonable. Changing this factor from 0.05 to 10.0 could reduce the maximum dissolved oxygen depletion (DO delta) by as much as 0.12 mg/l.

This is a calibration parameter, that is dependent on the characteristics of the system and the selection of the appropriate rate must be accomplished during the calibration phase. If there is a range of rates that are appropriate, then the modeler selects the best rate, usually the average rate, based on best professional judgment. Note for the initial modeling ATM selected a rate of 1 for the hydrodynamic modeling and a rate of 0.05 for the water quality modeling. It may have been more appropriate to use the same rate for both models but again this would have to be determined during the calibration process not during or after the TMDL modeling.

3) *CBOD Dissolved Fraction – This defines the amount of the total CBOD that is dissolved when discharged and is available to cause a decrease in oxygen levels. The assigned level for the present model simulations is 100%. This assumes all CBOD is immediately dissolved and is an ultra conservative assumption. Studies in areas such as the Potomac River Eutrophication Study have shown that the amount of CBOD actually available to be dissolved is nearer to 50%. Changing the CBOD Dissolved Fraction to 75% (still a conservative value) would reduce the overall DO delta by as much as 0.05 mg/l.*

The mentioned approach would be valid if the model was a carbon driven eutrophication model that addressed the labile and refractory components that are important in systems with long retention times and in which the algal kinetics must be addressed. But this model is a BOD-DO based model that uses QUAL2 kinetics, which is appropriate for the Charleston Harbor System.

4) Tidal Forcing – The TMDL simulations were performed with a synthetic tide, representing the annual average of the semi-diurnal components. Because the synthetic tides do not include meteorological tides (weather fronts and storms that usually cause mean sea level fluctuations) the assigned inputs are very conservative. This model input determines the effects of tide levels within the system. An increase in the tidal range results in greater tidal flushing, increased current flows, and reaeration within the system. By assigning conservative inputs, both the reaeration and flushing periods of the system are under predicted, thereby resulting in greater predicted DO delta.

The tidal forcing critical conditions used in the TMDL model were determined by EPA and the SCDHEC to be appropriate tidal conditions for TMDL development. They were not overly conservative. If the 1996 calibrated model conditions, with the actual 1996 tidal forcing, were used as the TMDL model the delta DO results would have been the same and If the 1993 calibrated model conditions, with the actual 1993 tidal forcing, were used as the TMDL model the delta DO results would have been 25% more stringent. Model runs with the original SCDHEC loadings produced the followng:

Model	Delta DO
TMDL	0.075 mg/l
1996	0.075 mg/l
1993	0.1 mg/l

5) CBOD Oxidation Rate - The assigned value for the CBOD rate in model runs to date has been 0.06 day^{-1}. … Therefore, the CBOD rate of 0.06 day^{-1} should be field verified to ensure accuracy.

The CBOD rate was used for the calibration models and was determined to be an appropriate rate. When additional data are collected during a good model calibration study, this rate can and should be revisited based on that additional data.

6) *Nitrification Rate The previous WQMAP application to Charleston Harbor Estuary utilized a conservative 0.3 day^{-1} nitrification rate to represent the kinetic pathway between ammonia nitrogen and nitrate, which is responsible for the Nitrogenous Biochemical Oxygen Demand (NBOD). … As part of EPA Region 4 review of the Draft TMDL document, a study was recommended to investigate the rate of oxidation for NBOD occurring in Charleston Harbor. Subsequently, three sampling events were performed for the Charleston Harbor NBOD Oxidation Rate Study. The sampling locations were distributed around the Charleston Harbor Estuary. Preliminary analysis of Event 1 LTBOD and NTS Laboratory tests data indicates a range of NBOD oxidation rates from 0.09 day^{-1} to 0.025 day^{-1}. The preliminary analysis also shows that a majority of the data are represented by generating a NBOD curve (DO concentration vs. elapsed laboratory test time) with an example oxidation rate of 0.03 day^{-1}. Comparing to an identical laboratory test performed for the 1999 Savannah River Data Collection Event supports the results of the Charleston Harbor NBOD Oxidation Rate Study preliminary analysis. A NBOD oxidation rate of 0.035 day^{-1} was determined appropriate for preliminary calibration runs of the 1999 application of WQMAP to the Lower Savannah River Estuary based upon the laboratory results. In this sensitivity analysis for the levels of nitrification rate measured in the Charleston Harbor Estuary, the model was not sensitive to variations of plus or minus 25 percent. This model coefficient variation resulted in only +2 and –3 percent change in the DO delta. However, a simulation of the 0.3 day^{-1} NBOD rate previously assigned resulted in an increase in the maximum DO delta by 19 percent. This illustrates the potential error resulting from using literature values in the absence of measured data.*

Concur and the more appropriate rate of 0.035 / day was used. Sinse this is based on data adjustment of this rate is not needed; the uncertainty of the Kn rate varying is low.

7) *Wind Speed - Wind blowing over the estuary causes reaeration of the surface water, thereby raising the DO concentrations. The 1 m/s was a default wind speed used in earlier alternatives. A wind speed of 2.7 m/s was assigned for the TMDL simulations, and it is the 25th percentile wind speed measured at Charleston Harbor. During model testing, small changes in wind speed (i.e., plus or minus 25 percent) had no effect on the DO delta. Therefore, the 90th percentile wind speed of 5.4 m/s was simulated to determine if the wind speed would induce*

any significant change in the maximum DO delta. The higher wind speed did result in a significant reduction in the maximum DO delta (19 percent). The results indicate that the wind has little effect up to a threshold value, and above that value wind has a much greater effect. Additional sensitivity analysis runs would be required to determine the threshold for wind effect. This phenomenon is consistent with the model formulation. In WQMAP, for each time step, the model calculates the hydraulic- and the wind-induced reaeration and utilizes the higher of the two. Because the water velocities in the system are usually high, the wind-induced reaeration is only important at slack water (high and low tides).

Not sure of the purpose of this comment, the model used a reasonable wind speed. The suggestion of using a 90% value not justified and should not even have been considered.

8) *The proposed TMDL compliance simulation*

This proposed TMDL model produces results similar to the EPA and SCDHEC model. The report provides support and justification for the TMDL parameter selection. The main difference is the *Horizontal Dispersion Rate which is a given physical property which was appropriately established during calibration of the 2-D model.*

9) *The proposed use of a monthly average DO delta of 0.1 mg/l (rounded).*

This is not a modeling decision but an application of the SC water quality standards. This is a SCDHEC decision on how the SC WQSs are applied.

10) *The modeling tool developed for the Charleston Harbor Estuary must be evaluated in light of the uncertainty of model coefficients and the limitations resulting from the simplifying assumptions. The range of load reduction scenarios as a result of the variability of model coefficients, such as nitrification rate, CBOD oxidation rate, and horizontal dispersion coefficients is considerably large.*

Concur that there is considerable uncertainty in the 2-D Charleston Harbor Model. Based on the TMDL regulations, the TMDL must contain a margin-of-safety to address this uncertainty. Options for addressing the model uncertainty is either assigns an explicit margin of safety based on the sensitivity analysis or incorporates an implicit margin of safety by using reasonably conservative modeling parameters and critical conditions. The EPA and SCDHEC TMDL model incorporates the implicit margin-of-safety approach by the selection of conservative modeling parameters and critical conditions. In my opinion, the use of other modeling parameters and critical conditions as indicated in the sensitivity report, would have required the use of an explicit margin-of-safety because of the demonstrated model uncertainty, and the resulting TMDL would have been similar.

11) Use of a two-dimensional model, as stated earlier, is capable of predicting, with reasonable accuracy, a change in dissolved oxygen within the range stipulated in the EPA "10% Rule." However, the modeling application is not robust enough to predict dissolved oxygen changes in the 0.1 mg/l range. Though the past modeling effort was "state-of-the-art" at the time it was implemented, it is not suitable for, and was never intended to predict dissolved oxygen changes definitively at a 0.1 mg/l level.

The model can not predict the absolute DO in the harbor to within 0.1 mg/l. But the purpose of this model was to look at DO deficits, wether the deficit is 0.1 or 0.3 mg/l, the model is perfectly capable and adequate to evaluate these changes.

12) Reports Recommendations

I concur with the recommendations for that:

1. Acquire field data to measure the three-dimensional hydrodynamic and water quality characteristics of Charleston Harbor sufficient for calibration of the three-dimensional model, including:
   - Hydrodynamic data: continuous measurements of water surface elevations, current magnitudes and directions (include vertical distributions and velocity point measurements) and discrete tidal discharge measurements.
   - Water quality data: continuous measurements of surface and bottom dissolved oxygen concentrations, salinity, pH, and temperature. Discrete sampling events should also be included.
   - Field studies to assess and measure key model inputs such as: sediment oxygen demand, primary production, and other water chemistry parameters parallel to the continuous hydrodynamic and water quality data collection.

2) A three-dimensional, prognostic, hydrodynamic, salinity, and water quality model of the Charleston Harbor System be developed and models such as the three-dimensional

version of a completely non-proprietary WQMAP or EPA's EFDC model are suitable for this purpose.

This work can be completed as a follow up to this TMDL and if the results indicate different wasteload allocation values, either more or less stringent, then EPA and SCDHEC can revisit the TMDL Until this happens, I still recommend using the existing model for TMDL and wasteload allocation purposes.

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APPENDIX G

PUBLIC NOTICES, REVISED DRAFT TMDL

PUBLIC NOTICE

NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD FOR WATERS AND POLLUTANTS OF CONCERN IN THE STATE OF SOUTH CAROLINA

November 5, 2002

Section 303(d)(1)(C) of the Clean Water Act (CWA), 33 U.S.C. ' 1313(d)(1)(C), and EPA's implementing regulation, 40 C.F.R. ' 130.7(c)(1), require the establishment of total maximum daily loads (TMDLs) for waters identified in ' 303(d)(1)(A) of the CWA. Each of these TMDLs is to be established at a level necessary to implement applicable water quality standards with seasonal variations and a margin of safety, accounting for lack of knowledge concerning the relationship between effluent limitations and water quality. The South Carolina Department of Health and Environmental Control (SCDHEC) has developed a proposed TMDL for the Cooper River, Wando River and Charleston Harbor, Charleston, Berkeley and Dorchester Counties. The pollutants of concern are oxygen demanding substances: carbonaceous and nitrogenous biochemical oxygen demand. The TMDL indicates that a reduction in permitted loading of oxygen demanding substances to the system of approximately 70% is required to meet applicable water quality standards. SCDHEC is proposing to implement the TMDL in two phases: Phase 1 interim limits with reductions of approximately 60% from current permitted loadings and Phase 2 final limits with reductions of approximately 70% from current permitted loadings.

Persons wishing to comment on the proposed TMDL or to offer new data regarding the proposed TMDL are invited to submit the same in writing no later than December 6, 2002 to the South Carolina Department of Health and Environmental Control, Bureau of Water, 2600 Bull Street, Columbia, South Carolina 29201, ATTENTION: Larry Turner. Mr. Turner=s telephone number is: 803-898-4005. His E-Mail address is: turnerle@dhec.state.sc.us

The proposed TMDL and the administrative record, including technical information, data, and analyses supporting the proposed TMDLs, may be reviewed and copied at 2600 Bull Street, Columbia, South Carolina between the hours of 8:00 a.m. and 4:30 p.m., Monday through Friday. Copies will be provided at a minimal cost per page. The draft TMDL documents will be available on the Internet at: www.scdhec.net/water/html/eqpnbow.html

After review and consideration of any comments and information provided during the comment period, the proposed TMDL will be sent to EPA for approval.

Please bring the foregoing to the attention of persons whom you believe will be interested in this matter.

NOTICE OF AVAILABILITY OF PROPOSED TMDL FOR WATERS AND POLLUTANTS OF CONCERN IN THE STATE OF SOUTH CAROLINA

The South Carolina Department of Health and Environmental Control (SCDHEC) has developed a proposed total maximum daily load (TMDL) for the Cooper River, Wando River and Charleston Harbor in Charleston, Berkeley and Dorchester Counties. This TMDL has been developed in accordance with Section 303(d) of the Clean Water Act and SCDHEC is now proposing to establish it as a final TMDL.

Persons wishing to offer comments regarding this proposed TMDL may submit comments in writing not later than December 6, 2002, to Larry Turner, SCDHEC, Bureau of Water, 2600 Bull Street, Columbia, SC 29201 or via E-mail at: turnerle@dhec.state.sc.us For more information please contact Mr. Turner at (803) 898-4005. A copy of the TMDL report will be available on the SCDHEC web page at: www.scdhec.net/water/html/eqpnbow.html

APPENDIX H

RESPONSIVENESS SUMMARY TO PUBLIC COMMENTS
ON THE
REVISED DRAFT TMDL

Summary of Public Comments and Departmental Responses
For Revised Draft Total Maximum Daily Load (TMDL) For The
Charleston Harbor System
December 16, 2002
(Based on November 5, 2002 Draft TMDL Notice)

Note: The Department received comments from several commenters regarding the revised draft TMDL. Respondents included governmental entities, private industries, and one environmental group. The Department has organized this responsiveness summary so that the comments will appear grouped by the issues to which they apply. There is no inference of importance or meaning given to the order in which the comments are addressed. Those commenting on the revised draft TMDL are:

US Environmental Protection Agency
MeadWestvaco Corporation
Berkeley County Water and Sanitation Authority
Cooper River TMDL Coalition, composed of:
- Bayer Corporation
- Berkeley County Water and Sanitation Authority
- MeadWestvaco Corporation
- Charleston Commissioners of Public Works
- North Charleston Sewer District

South Carolina Department of Natural Resources
South Carolina Coastal Conservation League

1. Comment: Several commenters stated that they support the Berkeley-Charleston-Dorchester Council of Governments (COG) efforts to develop a 3-D model of the Charleston Harbor system; however, they expressed concern that due to factors beyond their control, the modeling effort and Department review may not be completed prior to required implementation of final TMDL limits. They requested the Department reconsider incorporating into the TMDL language proposed by the COG, which would delay implementation of final TMDL limits if 3-D model development were delayed for any reason.

Response: The Department has accepted phasing of the current TMDL to provide reasonable time for development of a comprehensive, 3-D model of the Charleston Harbor system; however, implementation of final TMDL limits in a set timeframe is imperative to establishment of a phased TMDL. If the modeling effort is not completed in the specified time frame, the Department will consider the reason when proceeding with final TMDL implementation. If an acceptable, properly documented model is provided to the Department within the specified time frame, and for some reason within its control the Department is unable to complete its review and approval, implementation of final TMDL loadings may be temporarily deferred. If, however, the modeling effort is not completed in a timely manner due to the inability of the COG or its contractor to deliver an acceptable model, the Phase 2 loadings will be implemented as stated in the TMDL.

2. Comment: Several commenters suggested that TMDL loadings be required only for the months of June through September thus allowing less restrictive limits (some approaching or at guideline loadings) for the months of October through May.

Response: As required by R.61-68, the Department develops wasteload allocations for critical, low flow conditions. These allocations are applied through NPDES permits. In certain instances, less restrictive limits for biochemical oxygen demand and ammonia due to toxicity are allowed during cold weather, "winter" conditions. The temperature portion of the State/EPA agreement on wasteload allocations and TMDLs defines this period as November through February. Modeling is usually conducted using the critical month (usually November) temperature conditions to determine allowable limits. The Department has proposed to use this process to allow the Cooper River dischargers flexibility in meeting TMDL requirements.

3. Comment: Several commenters recommended inclusion of the maximum 10% Rule loading in the TMDL so that "no reopening the of TMDL would be necessary in the event of the Department's approval of a study result up to those loadings." Alternately, these commenters recommended processing any 10% Rule study and TMDL revision jointly.

Response: While the Department understands the commenters' desire to minimize the need for future revision of the TMDL, there are several factors that make inclusion of the "maximum 10% loading" in the current TMDL impossible. Section 48-1-83 of the Pollution Control Act lays out specific requirements for conducting a 10% Rule evaluation. It requires comparison of the waterbody in question with an appropriate reference site to determine: 1. If the depressed dissolved oxygen concentrations are truly natural and not caused by anthropogenic sources and, 2. What the natural background dissolved oxygen concentration actually is. A loading that would result in a 10% decrease in the DO concentration cannot be determined until the value that can be decreased by 10% is known. Additionally, to determine the loading, a model capable of modeling to a specific DO concentration, not merely a deficit from an expected value, is required. The existing 2-D model is not capable of doing this. Section 48-1-83 includes other requirements including identification of the resident species most sensitive to low dissolved oxygen concentrations and studies to determine the DO depression acceptable to that species up to a maximum of 10%. While certain dischargers advised the Department of a desire to pursue a 10% Rule evaluation and the required public hearing was held, we have not received the required study plan for such an evaluation and, to our knowledge, no work toward providing the required information has been developed. Because of these factors, it would be inappropriate to include any reference to a specific 10% Rule loading in the current TMDL.

4. Comment: One commenter supported the reductions and the phased approach and, while noting the existing evidence that portions of the system are experiencing stress from low dissolved oxygen concentrations, commended the Department on developing a protective TMDL.

Response: No response required.

5. Comment: One commenter noted that the process to develop the TMDL has been long and experienced delays. They recommend the Department hold firmly to the proposed schedule and not allow further delays.

Response: The Department has outlined a phased schedule for implementation of interim and final limits while allowing for additional modeling work, which may impact final TMDL limits. It is the Department's intention to proceed with this process in a set timeframe.

6. Comment: One commenter requested that the document list the ambient monitoring stations in the Ashley and Wando Rivers that are listed on the 303(d) list.

Response: The stations will be included in the report.

7. Comment: One commenter requested that the Department coordinate with the National Marine Fisheries Service or EPA's Endangered Species Coordinator to confirm that application of the 0.1 Rule will protect the short nosed sturgeon.

Response: The Department has provided Duncan Powell, EPA's Endangered Species Coordinator, a copy of the TMDL and the web address of the electronic copy of the TMDL to facilitate his review and coordination of endangered species requirements.

8. Comment: One commenter questioned whether the proposed TMDL is solely for ultimate oxygen demand (UOD) or whether allocations for other parameters (CBOD5, CBODU and NH3) will be included. They further suggested the need for an explanation of the relationship of UOD to CBOD5 and NH3.

Response: The objective of the TMDL is to limit the discharge of all oxygen demanding substances to the Charleston Harbor system, hence the limit on ultimate oxygen demand. The Department is less concerned with whether the demand is in the carbonaceous or nitrogenous form of oxygen demand. While in theory UOD could be the only parameter limited, with only monitoring and reporting required for the carbonaceous and nitrogenous BOD components of the total UOD, there are other NPDES permitting requirements that will mandate the inclusion of limits for BOD5 and NH3 in some permits. The text of the TMDL will be modified to better explain the components of UOD and how limits will be expressed on permits.

9. Comment: One commenter asked for clarification in the TMDL document on how the loading capacity of the allocated pollutant can be found and how this loading capacity was developed.

Response: The commenter is referred to the sections in the document concerning the TMDL calculator and local Council of Government involvement (pages 15 and 16 respectively) that explain how the actual loadings were determined and allocated.

10. Comment: One commenter requested the TMDL include the range of natural DO concentrations expected in Charleston Harbor to which the 0.1 Rule will be applied.

Response: We have reviewed the data collected by USGS as part of the Charleston Harbor Project and have determined the range of dissolved oxygen concentrations found during the critical, hot weather months at the stations evaluated in the 0.1 Rule justification review (see Appendix B). A table providing the range of DO concentrations found at each station is now included in Appendix B.

11. Comment: One commenter questioned the TMDL model's representation of the 500 mgd (nominal flow) cooling water discharge, and its associated dissolved oxygen concentration, at the Williams Steam Station. The commenter states the TMDL model includes the UOD from the station but does not include the associated flow and dissolved oxygen loading. The commenter concluded that if an appropriate DO mass loading was included for the cooling water discharge, as was done with other domestic and industrial process discharges, there would be no need for implementation of final limits.

Response: We believe the TMDL model's representation of the Williams Station is appropriate for the purposes of the TMDL. The model was calibrated using this approach and EPA followed this approach in its review of the TMDL model. It is apparent from the comments and conclusions provided to the Department that the commenter is not fully aware of how the model developed by Applied Technology and Management handles Williams Steam Station. The UOD from Williams Steam Station included in the TMDL model is not associated with the cooling water discharge. Rather, it represents the small sanitary wastewater flow from the facility and includes a DO component along with the UOD. The TMDL model does not include a point source input for the large cooling water discharge; however, it is incorrect to suggest that this flow and associated DO and other constituents are not included in the model. Like the calibrated model, the TMDL model simply keeps this flow in the Cooper River rather than routing the water and associated UOD and DO through the cooling water system. The cooling water flow, UOD, and DO are not omitted, they just follow a different path to get to the same point, the Cooper River at Williams Steam Station, the path that would be taken if the station were not discharging. This approach is consistent with the modeling of other large cooling water withdrawals/discharges throughout the state where there is considered to be no net loss or gain of DO or UOD associated with the cooling water systems. If the impact of the discharge were to be included, only the net increase in dissolved oxygen, over and above that already in the water, would impact the allowable TMDL load. This would be significantly less than the loading implied by the commenter. In any case, it would be inappropriate to include a net loading of DO from the project since, even though the steam station may operate most of the time, there is no requirement that it do so.